The American Biology Teacher

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The Teaching of Evolution

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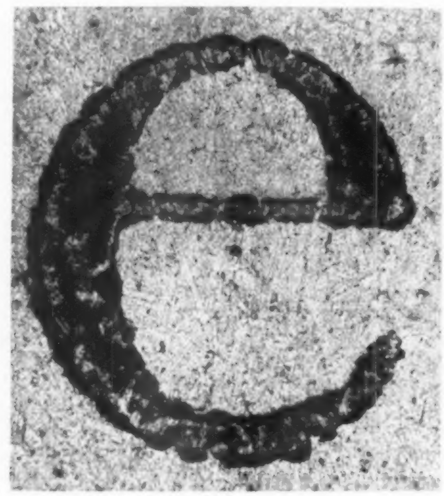
GS1



GS2

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TABLE OF CONTENTS

Cover Photo

This spider did a big job for the web shown here was about six feet in diameter. Taken by Ruby E. Wheeler, Frank Scott Bunnell High School, Stratford, Connecticut, a 4x5 Speed Graphic camera was used with Super Pan Press film and No. 40 flashbulb.

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Using Modern Knowledge to Teach Evolution in High School[1]

JOHN C. MAYFIELD, D. BOB GOWIN, and RICHARD BOYAJIAN
The University of Chicago, Chicago 37, Illinois

Introduction

During the last thirty years the rapid advance of scientific knowledge has substantially widened the gap between high school biology and biology as scientists see it. Professional biologists have become increasingly concerned that the high school course should be brought up to date and increasingly willing to participate in its improvement. And, more and more frequently, high school teachers of biology have expressed dissatisfaction with their own preparation and with the quality of the materials they have for use in the classroom. These common concerns of scientists and high-school instructors are the main justification for the experiences and suggestions recorded in this report.

As planning for the Darwin Centennial Celebration at the University of Chicago went forward, it became apparent that the Centennial would provide a unique opportunity to bring scientists and high-school teachers together as one step toward closing the gap between them in the area of evolution. The National Science Foundation (NSF) agreed to underwrite the cost of bringing some sixty high school teachers to the University campus for the five-day celebration, to constitute a "National Conference of High School Biology Teachers." Sixty-three members were selected for the conference from more than 260 persons nominated by directors of the 1959 NSF summer institutes. The selection was made so that all parts of the country and various types of schools would be represented.

The central feature of the Darwin Celebration was a series of panel discussions by noted scientists of five *Issues in Evolution:*

I. The Origin of Life
II. The Evolution of Life
III. Man as an Organism
IV. The Evolution of Mind
V. Social and Cultural Evolution

The panelists included physical scientists, biologists, and social scientists. Each one had prepared a special Centennial paper in line with his own interests and competence. These papers were made available in advance to all the other panelists, and summaries were prepared for the audiences. Other features of the celebration included a convocation at which several honorary degrees were awarded, and a musical, "Time Will Tell," based on the life of Charles Darwin and written especially for the occasion. The Centennial papers, addresses, and panel discussions are being published by the University of Chicago Press in three volumes under the title, *Evolution After Darwin.*

Each member of the High School Conference read several of the Centennial papers, attended the panel discussions and other general meetings. In addition there were four special conference sessions. Two of these, which were open to other science teachers in the area, included talks by Edgar Anderson, Theodosius Dobzhansky, Sir Julian Huxley, Hermann J. Muller, George Gaylord Simpson, and Nikko Tinbergen. These men expressed their views on the teaching of evolution and discussed questions raised by the high school teachers. The members met twice in smaller discussion groups to deal with the problems of teaching evolution. At the close of the five-day conference, each of the members submitted a short paper in which he summarized his view of the problems and suggested ways in which modern knowledge of evolution might best be utilized with high school classes.

The participating teachers may be assumed to be familiar with the teaching of evolution in representative high schools with respect both to attitudes and procedures and to the treatment of the subject in high-school textbooks. Attendance at NSF summer institutes would indicate a reasonable knowledge of modern science in general. Reading of the

[1]This report of the High School Conference of the Darwin Centennial Celebration, The University of Chicago, November 24-28, 1959, together with an article by Sir Julian Huxley has been published in pamphlet form and may be obtained from Professor Mayfield.

Centennial papers and attendance at the panel discussions brought them into contact with scientists' most recent thoughts on evolution and stimulated them to consider how it can best be taught to their students. Their papers should thus throw significant light on the present state of the teaching of evolution and how it may be improved.

This report is based on the papers prepared by members of the conference while they were in Chicago, the records of their discussion sessions, and the talks made to them by biologists. It presents the more important ideas expressed and the problems identified rather than a statistical summary or a set of recommendations agreed on by the members. As such it is hoped that it will be helpful to those who attended and to other teachers of biology.

Areas of Modern Knowledge for Use in High School

A hundred years ago Charles Darwin sketched out the major features of the evolutionary process. Marshalling the geological and biological knowledge of his time, and adding new information and new insight, this book, *The Origin of Species*, ultimately convinced the scientific world that biological evolution had indeed occurred. The different lines of evidence for evolution which he presented are still basically sound: domesticated plants and animals, paleontology, comparative anatomy, embryology, taxonomy, geographic distribution, and adaptation. The early Twentieth Century saw his erroneous concepts of the nature of heredity and heritable variations corrected, but his central idea that evolution occurs as the result of variation and natural selection stands unchanged. During the last thirty years, the frontiers of evolutionary knowledge have advanced in several directions, some of them only vaguely hinted at in 1930. Speculation and hypothesis based on the new knowledge have reached even further.

When our high school biology courses are examined, it becomes obvious that they have not kept up with advances in biological knowledge. Textbooks are badly out of date. Some treat the subject of evolution inadequately, and some do not treat it at all. Many teachers, even those who were at one time adequately trained, have not followed the newer developments. With these inadequacies apparent, two questions occur: What are the main areas of new knowledge from which our courses should draw facts and ideas for teaching evolution in high school? What are the directions in which knowledge is now growing most significantly?

We have not attempted to present here a summary of the new knowledge. For such information reference should be made to the Centennial publication, *Evolution After Darwin*, and to other books listed near the end of this article. Instead we have indicated those areas from which new material can be drawn, emphasizing the ones which members of the High School Conference felt had the greatest potential value. It must remain for energetic and up-to-date teachers, with the help of scientists, to select and try out such parts of the new knowledge as seem to have educative value for high school students.

One of the outstanding areas for attention is the chemical nature of living matter and of life processes. Much has been learned about the complex enzyme systems which participate in synthesizing and utilizing the materials of life and which are strikingly similar in all organisms from the lowest to the highest. The chemical nature of genes is being gradually unravelled through study of the heredity of bacteria, through investigations into the content and behavior of viruses, through chemical study of DNA (deoxyribonucleic acid, one of the key constituents of viruses and genes), and through relating specific enzymes to mutations of genes.

Another area, closely related to the first, which is receiving much attention is the preorganic origin of organic compounds and the possibility of the spontaneous origin of life (biopoesis) on this and other planets. Much of the thought in this area is highly speculative, but experiments have shown that substances as complex as amino acids and combinations of them can be produced by applying the energy of electrical discharges or ultra-violet light to simple inorganic substances believed to have been present on the earth millions of years ago. The concept of natural selection has been applied to highly complex molecules with the conclusion that the formation of photosynthetic pigments and DNA might have come about in some such way. Statistical studies of the number of stars in the universe and the probable number of planets around them, along with modern estimates of the age of the universe, lead to the conclusion that

similar types of creation may have occurred many times.

Although knowledge of paleontology was one of the primary stimuli leading to the concept of evolution, gaps in the fossil record are being steadily narrowed by new finds. These include additions to plant and animal collections, but those having to do with man have attracted much recent attention. Africa has been the source of many human and subhuman fossils which help to reveal primate relationships. The more complete fossil record is leading into study of the ecology of human evolution. New methods of dating and the wider application of older methods are developing more accurate indications of the time which has been available for evolution to occur and of the age of various groups of organisms.

Darwin's bold outline of the general method of evolution is today being filled in with more and more details. These details are found in the origin and fate of mutations, in a multitude of observed cases of selection, in the genetic constitution of populations, in the changes in populations even from season to season, in the effect of chance on evolutionary change, and in the patterns which the process seems to follow; e.g., stabilization of forms with types of reproduction which prevent variation over long periods followed by break-throughs in which there is rapid change. Even though much knowledge is available in these and similar areas, scientists are in doubt about many aspects of evolution, and these doubts lead to differences in views. These doubts and differences themselves are a source of teaching material if we hope to reveal to our students the nature of science and of scientific progress.

It was indicated above that knowledge of the physical evolution of man and of the factors involved has been increased by recent fossil finds. Other problems under intense study deal with the development of man's brain and intelligence and the part which these have played and will continue to play in his evolution through the culture and society which they produce. Here biology merges with the social studies, and these two areas may well share responsibility for the selection and use of modern knowledge.

Man's control over his environment has led to greatly increased human survival rates and thus to a rapid increase of the world's population. How knowledge and intelligence may be applied in dealing with this population increase and with man's further evolution constitute questions appropriate for consideration in biology courses.

Implicit in this brief sketch of the source material available for organizing the modern study of evolution is the idea that evolution by variation and selection is a concept which can be applied all the way from the formation of the first organic molecules across the world of plants and animals to the physical and mental development of man and even to his society and culture. Realization of the broad usefulness of this concept was, for many members of the High School Conference, an outstanding product of their participation in the Darwin Centennial.

Objectives of the Study of Evolution

Merely to tell students the "facts" of evolution, either orally or by means of the printed page, and to have them repeated as told, will accomplish the purposes of teaching to only a small degree. Indeed, it is likely to interfere with some of the kinds of growth we wish to bring about in our students. As biology teachers we must therefore have clearly in mind those changes in thinking and attitudes which we wish to produce. Of course, we cannot expect these changes to occur to the same extent in all students. The outcomes selected as desirable are the ideal ends of our teaching; for our own morale we need to think of them as directions of growth. Yet by thinking of them in this sense we must not be led to take an easy-going attitude nor to neglect those objectives which are less tangible than the memorization of factual statements. What, then, are the central objectives in teaching evolution?

In the first place, and as means of attaining other ends as well, we seek to develop in students a basic knowledge of evolution. This includes an understanding of the biological meaning of the term evolution and of the various lines of evidence supporting the conclusion that it has occurred. To be functional, this knowledge requires as its foundation a considerable understanding of the physical and chemical nature of living things. Beyond what is usually considered biology, students should gain some understanding of current views of inanimate evolution and of the evolution of

languages and cultures. Just as Darwin found it necessary to support his view of the existence of evolution with a mechanism by which it could have come about, we must seek to develop in our students a reasonable understanding of the main factors in the process and the way they work together to bring about changes in structure and function.

Properly taught, the knowledge which our students gain should produce in them a sense of the universality of evolutionary processes, from the pre-biological molecular level through the pre-human world to man with his physical, mental, and socio-cultural development, thus integrating the physical, biological, and social sciences, and, through history, the humanities. This sense of change leads to the "habit of thinking of reality in terms of process,"[2] rather than in terms of static situations. The person who has acquired this habit realizes that evolution is constantly going on all about him. Out of this study should also develop an appreciation of the accomplishments of evolution in bringing about the fine adaptations of plants and animals to the many living and nonliving aspects of their environments, and of the practically incomprehensible span of time which has been available to bring about these adaptations.

By learning how our knowledge of evolution has developed and how many problems are still unsolved, students should develop an increased grasp of the nature, powers, and limitations of science and scientific method. Accompanying this understanding should come an increased desire to use scientific method wherever it is applicable.

Knowledge of evolution will not have accomplished its full educative effect on students unless it is accompanied by increased ability to see, in the world about them, problems of theory and fact related to this area, and to use their knowledge in thinking about such problems. These problems range from those involved in the adaptation of bacteria and insects to new drugs, to those connected with the growth and control of human populations.

Finally, and probably most important, the study of evolution should be so conducted as to leave the student with increased and continuing interest in the area. As a result he will extend his acquisition of current knowledge beyond that presented in school and will follow new developments as information about them becomes available.

Teaching Evolution to Promote Growth in the Desired Directions

It has become trite but no less true to say that evolution is the greatest unifying concept in biology. Incorporated into a person's thought system, it modifies his way of looking at all biological phenomena. Thus, if one has really acquired this concept it changes his way of thinking about each topic or unit in a biology course. Because of these facts several of the great biologists who spoke at the conference were strongly in favor of teaching evolution all through the biology course instead of limiting its consideration to one unit near the end of the course as is so commonly done. For example, Sir Julian Huxley said, "It is a shame. . . . that evolution has not been allowed to take its place in education, both as an important single subject and as an organizing, centralizing, unifying idea."[3] Later G. G. Simpson said, "We give a false picture if we teach evolution only in a single chapter of its own." Most of the teachers present felt that evolution should be taught throughout the course, but a few were doubtful of the wisdom of doing this. It seemed unwise to the latter group to introduce the concept at a time when the students know very little biology, and to begin using it authoritatively before having introduced their students to the idea gradually and inductively.

There was general agreement that, in teaching evolution, much use should be made of modern observations and experiments that illustrate and clarify the process. Frequently mentioned were the Miller-Urey experiments in the formation of amino acids and other organic compounds from simpler substances by electrical discharges, the development by bacteria of resistance to viruses and to antibiotics, and the development of industrial melanism in moths. However, there is still a recognized need for practical classroom experiments and observations which illustrate the process effectively and correctly.

[2] Sir Julian Huxley, "Evolution in the High School Curriculum," *School Review*, IXVIII, Summer, 1960, p. 167.

[3] ibid, p. 164.

The organization of the Centennial emphasized a unified view of evolution from the nonliving world through the world of biology into the world of the social sciences. In general, the teachers attending the conference were quite willing to admit that evolution of a kind occurs in all these areas. However, most of them felt that they have quite enough to do if they deal briefly with the possibility of the chemical origin of life and do an adequate job of teaching evolution as it applies to the plant and animal kingdoms. They are willing to note the connection between man's intelligence and manual dexterity and the evolution of culture and society, but they prefer to leave detailed work in these areas to teachers of the social sciences.

Members of the conference were strongly impressed by the scientists' complete acceptance of evolution as a fact, by their willingness to say, at many points, that they did not know enough to answer their own questions, and by their friendly but pointed disagreement about some conclusions. They felt that communication of such attitudes to their students is very important. In this way and through some study of the history of the evolutionary concept, they could help students grasp the open-ended, inquiring aspects of the scientific enterprise.

Problems Involved in Teaching Evolution in High School[4]

In spite of enthusiasm generated by the atmosphere of the Centennial Celebration and contact with so many scientists seriously considering what is known and what is unknown about evolution, the members of the conference recognized that, if American high schools are to do an adequate job of teaching this subject, a number of serious problems must be solved. First and foremost is that of helping teachers obtain adequate and reasonably up-to-date knowledge in the area. In spite of the recent publication of a number of good books and magazines articles and the opportunity to attend summer institutes, many teachers seem satisfied to depend on knowledge remaining from their college courses of years ago and on the often inadequate content of high school textbooks. Frequently their knowledge from college course work has been deficient in the area of evolution, especially for the large number of biology teachers who did not specialize in biology in college and for those trained in colleges where there is religious opposition to the idea of evolution.

It has already been pointed out that high school textbooks are notoriously inadequate in their treatment of evolution Frequently they avoid the subject or treat it under some less controversial heading. Even when the subject is treated openly, the use made of modern knowledge can seldom be considered adequate.[5] Where teachers wish to supplement the textbook they find it impractical to obtain suitable reading material for all their students. As a result, teaching that can be considered adequate from a modern point of view often becomes very difficult, if not impossible.

Enthusiastic teachers propose that, with the help of scientists, they urge publishers to produce textbooks that treat evolution openly and adequately. They also suggest that teachers who believe in teaching the subject make special efforts to obtain positions on textbook selection committees and work for approval of the books that treat the topic most suitably.

Even when the teacher is well prepared and there is appropriate reading material on evolution, other, traditional topics fill the time and crowd the unit or chapter on evolution to the end of the course and, often, entirely out of it. Careful evaluation of the relative importance of traditional biology content is in order. Time for a more thorough treatment of evolution may well be found by discarding much of the usual descriptive material which is not truly illuminating for students, as well as much nonessential terminology. At one point Professor H. J. Muller said, "We have dosed our pupils far more today than we should. Technical terms seldom need to be taught. They detract from the understanding of process. Let pupils see the forest instead of too many trees." Just which traditional material is least valuable and which technical terms are least significant and useful are problems for long-term investigation. It is to be hoped that the Biological Sciences Curriculum Study now under way will

[4]See also David C. Evans, "Problems of Teaching Evolution in the Secondary Schools," *The American Biology Teacher*, XXII, 221-3 (April, 1960).

[5]See H. J. Muller, "One Hundred Years Without Darwinism Are Enough," *School Science and Mathematics*, LIX, April 1959, pp. 304-316.

make significant progress toward their solution.

A problem which is more serious and less susceptible to systematic attack is that raised by religious opposition to the teaching of evolution. However unjustified scientists and some religious groups may consider such opposition, it is wide-spread and effective. It is firmly rooted in an essentially anti-scientific approach to the natural world, and is supported by law, by school boards whose members agree with the opposition, and by school administrators who dare not permit the use of controversial material in their schools. As a result effective study of evolution is prevented in many communities. By interfering with the sale and use of textbooks it, in effect, censors those that are most widely used. Colleges that are controlled by anti-evolutionist groups may not deal with evolution in their own biological courses, especially in those general education courses most apt to be taken by future teachers. Thus the opposition also interferes with the development of teachers who are convinced that evolution is a fact rather than an invention of the devil working through irreligious scientists.

Teachers who believe that the study of evolution is an essential part of the modern high school biology course propose a number of modes of action to overcome opposition to teaching it. The more optimistic propose widespread efforts to convince the public of the truth of evolution. They suggest talks to community groups by scientists and teachers, student-led panels before such groups, more popular articles in widely-read periodicals, and other similar approaches designed to change the views of citizens. Others advocate adapting the classroom approach to the school and community situation in at least three different ways: (1) Point out to students that while some people, including perhaps some of them, do not accept the idea of evolution, it is important for an intelligent person to know what others believe and why, without necessarily agreeing with them; (2) teach evolution as applying to plants and animals but stop short of man, and leave students to develop their own private opinions as to the universality of the process; (3) teach evolution under the name of "biological change" or "development," thus avoiding the controversial term. Some teachers consider the second and third methods essentially dishonest and unsuited to a science course. Others feel that the name used is unimportant, and that it is the ideas that are essential. None of these approaches really solves the problem and there seems little doubt that many biology teachers must continue to live with it.

In connection with religious attitudes toward evolution, there was general agreement among the members of the conference that, where students are emotionally convinced that one cannot accept the idea of evolution and, at the same time, believe in the Bible and in God, teachers are obligated to move carefully and with all due consideration for the emotional welfare of their students.

The last major problem to be mentioned is that of the intellectual and educational maturity of high-school students. To feel the force and illuminating value of the modern concept of evolution, they need considerable factual background in both biology and chemistry. Further, it may be argued that a certain degree of intellectual maturity is required (1) to find interest in consideration of such a broad concept, (2) to understand how the facts of biology lead to the concept of evolution and convince scientists that it is itself one of the facts and (3) to grasp in any reasonable degree the significance of the concept in other areas of biology. Without such background and maturity evolution is apt to be taught as a dogma for acceptance without intellectual examination. To what extent this is desirable is somewhat problematical. It is possible that it should be so taught in the upper grades of the elementary school and the lower grades of the high school leaving critical examination of the concept and its basis for a later time. One serious difficulty with this plan is that those who have no further formal contact with biology are apt never to make that critical examination.

Changes now going on in the placement of science courses tend to increase rather than decrease the intensity of the problem of student maturity. Traditionally biology has been a tenth-grade subject, usually preceded by a year of general science in the ninth grade. Today, biology is rapidly being moved into the ninth grade and whatever general science instruction can be counted on is that which occurs in the earlier grades. Thus, both the

amount of scientific knowledge and the level of maturity of the students are likely to be somewhat lower than in the past. On the other hand, there is some evidence that we tend to underestimate the extent to which boys and girls can grasp scientific concepts when they are properly presented. This may be true of the concept of evolution. Certainly this is open to investigation. Vigorous experimentation should be instituted at once to determine which aspects of evolution can be taught effectively in the high school biology course and which should not be attempted.

Summary

Knowledge of biology related to evolution has developed rapidly during the last thirty years. Probably the outstanding advance has occurred in the area of biochemistry, in knowledge of such things as the chemical structure of genes and the chemistry of metabolism. Much thought and some experimentation has also been given to the possible origin of life from organic materials formed in an early period of the earth's history and in other solar systems. Many new fossils have been found to narrow the gaps in the story of life. The actual processes of evolution among living organisms have been widely analyzed, observed, and experimented with.

Knowledge of the physical development of man as recorded in fossils has increased greatly and there has been much study of the brain and intelligence, and of the evolution of culture and society. And there is much concern about the use of human intelligence for directing and controlling future changes in human populations.

In considering how to select and use modern knowledge in teaching evolution, those aims of education that lie beyond the memorization of information and scientific principles must always be kept in mind. True education calls for growth of insight and changes in attitude as well as the development of new and more mature interests. In the light of these goals, careful consideration must be given to the way in which the concept of evolution is to be introduced and used in high-school biology, whether it is to be taught and used throughout the course, or whether there should be a major unit which develops the concept and the evidence for it after which it is used and applied. Whichever way it is taught, modern biology needs to be searched for observations, experiments and concepts useful in teaching the topic to high-school boys and girls. Consideration should also be given to relating classroom biology to the study of culture, society and psychology in social science courses.

Opportunities for improving the teaching of evolution are matched by serious problems. A high percentage of teachers need additional knowledge. Reading materials for high-school use are inadequate and outdated. The biology course is already crowded with content. Many high school students lack the conceptual background and maturity to consider evolution as an intellectual problem. And, most serious of all, in many communities the topic is a controversial one, highly charged with emotion. In communities where this problem exists the biology teacher's combined responsibility to science, to his individual students, and to the community is very difficult to carry out.

Scientists and teachers alike have a heavy obligation to bring modern knowledge of evolution into the high school classroom and, by careful investigation, to determine how best to use it in developing a more accurate view of man's place in nature and of the human problems which the concept illuminates and may aid in solving. In this report are recorded what seemed to members of the High School Conference the main opportunities and the main problems we face in meeting this obligation.

Modern Readings on Evolution

The following list of books has been prepared for teachers and others who may wish to renew their knowledge of evolution. It includes readings at a variety of levels, a number being suitable for use by high school students. See also recent volumes of the *Scientific American* for a number of helpful articles.

Andrews, H. N., *Ancient Plants and the World They Lived In.* New York: Comstock Publishing Co., 1947.

Blum, H. F., *Time's Arrow and Evolution.* New York: Henry Holt and Co., 1951.

Carter, G. S., *Animal Evolution.* London: Sidgwick and Jackson, 1951. (Intermediate level textbook.)

Clark, W. E. Le G., *The Fossil Evidence for Human Evolution.* Chicago: The University of Chicago Press, 1935.

———, *The Antecedents of Man.* Chicago: Quadrangle Books, 1960.

Darwin, Charles, *The Origin of Species.* New York: New American Library of World Literature, Inc., (Mentor Book No. MD 222) Various other editions are available.

Dixon, M., *Multi-Enzyme Systems.* London: Cambridge University Press, 1949.

Dobzhansky, Th., *Evolution, Genetics and Man.* New York: John Wiley and Sons, Inc. 1955.

———, *Genetics and The Origin of Species* (3rd Ed.) New York: Columbia University Press, 1951.

Hardin, Garrett, *Nature and Man's Fate.* New York: Rinehart Publishing Co., 1959.

Howells, William, *Mankind in the Making.* New York: Doubleday and Company, 1959.

Huxley, J. S., *Evolution in Action.* New York: Harper and Brothers, 1953. Also Mentor Book No. MD 204, 1957.

———, *Evolution, The Modern Synthesis.* New York: Harper and Brothers, 1943.

Lack, D., *Darwin's Finches.* London: Cambridge University Press, 1947.

Mayr, E., *Systematics and the Origin of Species.* New York: Columbia University Press, 1942.

Meggers, Betty J., (ed.), *Evolution and Anthropology.* Washington, D. C.: The Anthropological Society of Washington, D. C., 1959.

Moody, P. A., *Introduction to Evolution.* New York: Harper and Brothers, 1953. (Intermediate level textbook.)

Moore, R., *Man, Time, and Fossils.* New York: Alfred E. Knopf, 1953.

Oparin, A., *Origin of Life on the Earth*, 3rd Ed. New York: Academic Press, 1957. Also a Dover Book.

Pfeiffer, John, *From Galaxies to Man.* New York: Random House, 1959.

Redfield, R., *The Primitive World and Its Transformations.* Ithaca, New York: Cornell University Press, 1953.

Roe, Anne, and Simpson, G. G., (eds.) *Behavior and Evolution.* New Haven: Yale University Press, 1958.

Romer, A. S., *The Vertebrate Story* (Revised edition of *Man and the Vetebrates*) Chicago: University of Chicago Press, 1959.

Simpson, G. G., *Horses.* London: Oxford University Press, 1951.

———, *Life of the Past.* New Haven: Yale University Press, 1953.

———, *The Major Features of Evolution.* New York: Columbia University Press, 1953.

———, *The Meaning of Evolution.* New Haven: Yale University Press, 1949. (Also Mentor Book No. MD 66.)

Simpson, G. G., C. S. Pittendrigh and L. H. Tiffany, *Life: An Introduction to Biology.* New York: Harcourt, Brace and Company, 1957. A college-level textbook by three leading biologists in which the authors have "tried to make evolution as pervasive as it really is in the world of life."

Smith, J. M., *The Theory of Evolution.* New York: Penguin Books (No. A 433), 1958.

Tax, Sol (ed.), *Evolution after Darwin*, 3 vols.: *The Evolution of Life; The Evolution of Man; Issues in Evolution.* Chicago: University of Chicago Press, 1960. Publication of the University of Chicago Darwin Centennial Celebration, 1959.

Teilhard de Chardin, Pierre, *The Phenomenon of Man.* New York: Harper and Brothers, 1959.

Waddington, C. H., *The Strategy of the Genes.* New York: The Macmillan Company, 1957.

White, Leslie A., *The Evolution of Culture.* New York: McGraw-Hill Book Co., 1959.

Participating Members of Conference

Alabama: James H. Kincaid, Thorsby High School, Thorsby, Alabama.

Arizona: Glenn Rothrock, Catalina High School, Tucson, Arizona.

Arkansas: Maude Reid, Little Rock Central High School, Little Rock, Arkansas.

California: Robert L. Eicholtz, Sierra High School, Whittier, California; Thomas A. Steyaert, Mt. Diablo High School, Concord, California; Robert E. Wright, University High School, Los Angeles 25, California.

Colorado: Wesley A. Hall, Douglass Junior High School, Boulder, Colorado.

Connecticut: Jack W. Cohen, E. O. Smith School, University of Connecticut, Storrs, Connecticut.

Delaware: Chester A. Waller, William C. Jason High School, Georgetown, Delaware.

Florida: Carl G. Zweig, Sarasota Junior High School, Sarasota, Florida.

Georgia: Mrs. George F. Strother, Jr., Athens High School, Athens, Georgia; Mrs. Martha H. Thurmond, East Atlanta High School, Atlanta 16, Georgia.

Idaho: Allen J. Hollenbeck, Boise High School, Boise, Idaho.

Illinois: Robert W. Adams, The Allendale School, Allendale, Illinois; Robert L. Smith, DeKalb Senior High School, DeKalb, Illinois; James F. Ward, East High School, Rockford, Illinois.

Indiana: James L. Early, Central High School, South Bend Indiana; John B. Riggs, Kokomo, Indiana.

Iowa: Richard F. Trump, Ames Senior High School, Ames, Iowa; Roger Volker, Estherville High School, Estherville, Iowa.

Kansas: Cecil Raymond Goble, High School North, Wichita, Kansas.

Kentucky: Mrs. John W. Brake, Cumberland County High School, Burkesville, Kentucky.

Louisiana: Julia Frances Hamlet, West Jefferson High School, Harvey, Louisiana; John R. Middleton, Bolton High School, Alexandria, Louisiana.

Maine: Claude Bonang, Brunswick High School, Brunswick, Maine.

Maryland: Mozella T. Harris, Douglass Junior-Senior High School, Upper Marlboro, Maryland.

Massachusetts: William F. Favorite, Wilbraham Academy, Wilbraham, Massachusetts; Paul A. Hopkins, Andover High School, Andover, Massachusetts.

Michigan: Howard L. Faber, Saginaw High School, Saginaw, Michigan; Mary K. Hartz, Community College, Muskegon, Michigan; Helen M. Monroe, Cass Technical High School, Detroit 1, Michigan.

Minnesota: Ronald Keith Gibbs, Alexander Ramsey High School, St. Paul 13, Minnesota; Floyd H. Nordland, Richfield Senior High School, Minneapolis 23, Minnesota.

Mississippi: Claude L. Stuart, Greenville High School, Greenville, Mississippi.

Missouri: Kenneth Henry, Lebanon High School, Lebanon, Missouri.

Montana: Douglas Fox, Darby Consolidated School, Darby, Montana.

Nebraska: Harold W. Eggen, Central High School, Omaha 2, Nebraska.

New Hampshire: Robert G. Hindmarsh, The Meeting School, Rindge, New Hampshire.

New Jersey: Joseph A. DelVecchio, Jefferson High School, Elizabeth, New Jersey; Dean M. Laux, Glen Rock Jr. High School, Glen Rock, New Jersey.

New Mexico: John Thomas House, Alamogordo High School, Alamogordo, New Mexico.

New York: Kenneth Bobrowsky, Bronx High School of Science, Bronx 68, New York; Richard L. Petersohn, Harborfields Senior High School, Greenlaw, L. I., New York; Robert Edward Richmond, Garden City Senior High School, Garden City, New York; Morton G. Stone, Fort Hamilton High School, Brooklyn 9, New York.

North Carolina: Jean B. Worsley, Sterling High School, Pineville, North Carolina.

North Dakota: Alvin Ollenburger, Wimbledon Public School, Wimbledon, North Dakota.

Ohio: Patricia S. Mallory, Whitmer High School, Toledo 13, Ohio; Mrs. Mary C. Zambon, Xenia Central High School, Xenia, Ohio.

Oklahoma: David L. Foster, Nathan Hale High School, Tulsa, Oklahoma.

Oregon: Clement Arnold, Jr., Philomath High School, Philomath, Oregon.

Pennsylvania: Louis J. Borelli, Westinghouse Senior High, Pittsburgh 8, Pennsylvania; Richard L. James, Radnor Senior High School, Radnor, Pennsylvania; Richard S. Smith, Haverford Township Senior High, Havertown, Pennsylvania.

Puerto Rico: Mrs. Astrid Ll. Favra, Republic of Columbia Senior High School, Santurce, Puerto Rico.

South Carolina: William Brooks Hubbard, Hanna High School, Anderson, South Carolina.

Tennessee: Leon Donald Stancliff, Joelton High School, Joelton, Tennessee.

Texas: Shirley R. Bassett, Pasadena Senior High School, Pasadena, Texas; Jack D. McCullough, Jesse Jones Senior High School, Houston, Texas; Joe W. Tyson, Jr., William B. Travis High School, Austin 1, Texas.

Virginia: Mrs. Nancy S. Dickerson, Jefferson Senior High School, Roanoke, Virginia.

Washington: Robert J. Jonas, Pullman High School, Pullman, Washington.

Washington D. C.: Sister Mary Clare Fritsch, Immaculata High School, Washington 16, D. C.

Alfred Russell Wallace–Evolution's Forgotten Man

FLORENCE MOOG
Washington University, St. Louis, Missouri

The year 1959 was observed widely as the Darwin Centennial, the 100th year since Darwin's great book, *The Origin of Species*, first appeared on November 12, 1859. In England, in the United States, in many other countries throughout the world, people paused to commemorate this event, to celebrate it sometimes with elaborate programs and ceremonies. Meanwhile the presses poured out new books, by Darwin, about Darwin, about his friends, his contemporaries, his predecessors, his achievements. And no one can claim that this commemoration—the adulation, almost—was overdone. For the publication of *The Origin of Species* was one of the greatest events in man's intellectual history. By its timing, its content, its style, this book with one blow put an end to the old primitive poetic dream that man is God's special creation—his chosen animal—and showed us what our place in nature truly is.

Yet the date of that publication—1859—was no choice of Charles Darwin's. Had the matter been left up to him, the Centennial Year would still be in the future. Nor was the book that we know as *The Origin of Species* the book he had intended to write. What he would have written, had the choice been left to him, we can only speculate about. We can be pretty sure that it would have been a much longer book, and being longer, it might have been less widely read—the *Origin* was a best seller in 1860—and so it might have been less influential.

It is not that Darwin was unprepared to write his book in the late 1850's. He had been gathering the information and formulating the ideas for more than 20 years. But despite the urging of his friends, who knew the importance of what he was doing, he hesitated to put his work on paper. This is not very strange—Newton similarly hesitated for years before completing the work that revolutionized the science of physics. What forced Darwin's hand was the arrival of a letter and a few pages of manuscript from a man whom he had never met. The man of course was Alfred Russell Wallace. The little manuscript—it runs to about ten printed pages—was entitled, "On the tendency of varieties to depart indefinitely from the original type."

What was in this brief paper that forced Darwin to do what his friends could not persuade him to do? To answer that question, we have to try to recreate for a moment the intellectual climate of the time. In the first half of the 19th Century, the idea of evolution was not altogether strange. In those days the geologists were beginning to appreciate that the earth's crust had a history behind it, explorers were discovering that the earth was populated by more kinds of plants and animals than could have fitted into Noah's ark, and a lot of people were wondering about the frequent discoveries of fossilized bones of animals that no longer exist. Every now and then somebody expressed, more or less clearly, the idea that the plants and animals we see around us have not always existed, but have somehow developed or "evolved" from earlier, different forms. I say "somehow" evolved—and that was just the difficulty. No one was able to explain convincingly *how* one animal could give rise to another, different animal—and in the absence of such an explanation, most people clung to the comfortable old belief that God had done it all, in that miraculous week in which he created the firmament, and everything to go with it.

Such was the climate of opinion in 1831, when Darwin left England on HMS Beagle, a British naval ship sent out on a voyage of exploration. In those days the 22-year-old Darwin was furnished with a sufficiently orthodox set of religious views—he was in fact intended for a clergyman, the usual fate in those days of well-brought-up young men who didn't seem to be fit for anything else. But instead of taking a parish he sailed on the Beagle, and in the course of that voyage—it lasted 5 years—he had the opportunity to see many strange and wonderful things that revo-

lutionized his understanding of the world of life. In Uruguay he found beds of fossilized bones of animals that man had never seen alive in South America—a huge elephant, a giant armadillo, an ancient horse, a strange animal that was a little like a horse and a camel and an elephant rolled together. In Brazil he saw insects in an infinite variety of astonishing designs, designs that effectively protect the insects from the fate of being caught and eaten. And in the Galapagos Islands, most importantly, he saw what challenged his scientific imagination beyond anything else. The Galapagos are a group of inhospitable masses of black lava that lie in the Pacific, about 600 miles west of the coast of Ecuador. There, far out at sea, Darwin was astonished to find that the animals and plants were somehow familiar to him. These are his own words:

> "It was most striking to be surrounded by new birds, new reptiles, new shells, new insects, new plants, and yet by innumerable trifling details of structure, and even by the tones of voice and plumage of the birds, to have the temperate plains of Patagonia or the hot dry deserts of Northern Chile, vividly brought before my eyes. Why on these small points of land . . . were their aboriginal inhabitants . . . created on American types of organization?"

Nor was the strangely reminiscent character of the Galapagos flora and fauna all that attracted his attention. He goes on to point out something that surprised him even more:

> "I have not as yet noticed by far the most remarkable feature in the natural history of this archipelago; it is that the different islands to a considerable extent are inhabited by a different set of beings."

And here was a question: why should the animals and plants of the Galapagos be like those of South America? And why should they be different? Why should the pattern vary on islands only a few miles apart?

Observations like these, repeated over and over, produced in Darwin's mind the feeling that the creation of living things was based on some plan much more complex—and much more wonderful—than the simple tale of Genesis. Returning to England in 1836, after 5 years of voyaging, Darwin settled down at his quiet country home to work over his vast accumulation of notes and specimens, to learn as much as he could about the staggering variety of living things. Ultimately he hoped to explain how *new* animals and *new* plants come into being. He was still at work on that tremendous job when Wallace's letter arrived, in the spring of 1858.

Wallace was a much younger man than Darwin, and less fortunate. He came from a poor family, and from the age of 14 he had to make his own way—principally by surveying, and by teaching school. Fortunately there were good free public libraries in England in those days, and young Wallace read books that fired him with the ambition to travel in the tropics. In 1848, when he was 23, he sailed for South America with a friend, Henry Walter Bates. They spent four years canoeing up and down the Amazon, collecting specimens for the British Museum and for private collectors. Although the expedition was quite successful, Wallace was unlucky—the ship in which he was returning to England burned at sea, and he came home penniless and empty-handed.

But Wallace had years of observations stored in his capacious mind. From his store, he wrote a book, and soon he attracted the attention of people—they were numerous in England in those days—who were seriously interested in natural history. In 1853 the president of the Royal Geographic Society arranged for Wallace to go out to Singapore on a government vessel. That was the beginning of eight years of travels in the islands of the Malay Archipelago.

In those years Wallace travelled over 14,000 miles in the archipelago, and collected 125,000 specimens. Such statistics are easy enough to say, but one can scarcely imagine the courage and determination it required for one lone Englishman to perform such a feat in those days. One quotation from his autobiography will give you the idea; referring to one voyage in a Malay sailing vessel he says:

> "My first crew ran away; two men were lost for a month on a desert island; we were ten times aground on coral reefs; we lost four anchors; our sails were devoured by rats; the small boat was lost astern; we were 38 days on the voyage home that should have taken 12; we were many times short of food and water; we had no compass lamp owing to there being not a drop of oil in Waigiou when we left; and to crown it all,

during the whole of our voyage, occupying in all 78 days, we had not one single day of fair wind."

Exploring island after island, Wallace had the same kind of opportunities as Darwin had to see the staggering variety of living things that exist, to observe over and over how animals are precisely shaped or equipped in ways that make them best able to escape from their enemies, best able to secure the food they need to survive. Wallace too pondered about these things—how did these vast numbers of different kinds of living things come into being? What forces had fitted them so exactly to the lives they lead?

Darwin and Wallace had both read some of the same books. One book that strongly influenced them both was called "An Essay on Population," by Thomas Robert Malthus. The idea expressed in this book is that human beings tend to reproduce as fast as their food supplies allow—when plenty of food is available, more young are born and grow up: when supplies become short, many starve. Malthus of course was not interested in evolution. It was his purpose—a somewhat unchristian purpose, although he was a clergyman—to combat the social conscience that was growing up in the England of his time. He wanted to prove that it was useless to try to relieve the condition of the poor—because then there would only be more poor. Darwin and Wallace, who were both men of great humanitarian sympathies, ignored the purpose of Malthus' arguments, but they both saw a broader application of his principle. They saw that living things generally are being held in check by limitation of their food supplies, or by other kinds of adverse circumstances.

It was Wallace who put this principle to use most dramatically. In those days the price of travel in the tropics was to suffer recurrent fevers. One day in February of 1858, Wallace, lying in bed with a bout of fever, found his mind turning to Malthus. A question came to him: why, when conditions become difficult—when food is scarce, when the weather is severe, when the climate changes—why do some organisms die and some go on living? Then in a sudden flash he saw the answer: those survive that are best fitted to survive—the healthiest are safest from disease, the swiftest escape from their enemies, the keenest hunters get the most food.

And this is the point: animals are not all equally healthy, nor swift, nor strong, nor cunning. Wallace put it this way:

> "The numbers of wild animals that die annually must be immense; and as the individual existence of each animal depends upon itself, those that die must be the weakest . . . while those that prolong their existence can only be the most perfect in health and vigor—those who are best able to obtain food regularly, and avoid their numerous enemies. It is . . . a 'struggle for existence,' in which the weakest and least perfectly organized must always succumb."

Wallace saw clearly that variation did not occur because the animals *wanted* to change, or were *trying* to change—rather, variation just happens, and selective forces act on it. In the essay he sent to Darwin, he said, for example:

> "Even the peculiar colours of many animals, especially insects, so closely resembling the soil or the leaves or the trunks on which they habitually reside, are explained on the same principle; for though in the course of ages varieties of many tints may have occurred, *yet those races having colours best adapted to concealment from their enemies would inevitably survive the longest.*"

Now in these quotations we see stated, in a few words, what is really the basis of our present-day understanding of evolution: Evolution—the origin, that is to say, of *new* forms of life—occurs because living things always tend to differ from one another. In the face of changing external circumstances, those that can meet the challenge survive to produce more of their kind, others are eliminated. For example, when the climate becomes colder, as it has several times in the earth's history, those animals that can produce more heat, or can conserve their heat more efficiently, are favored—species with naked skins give rise to woolly ones, and so on. When the climate becomes drier, those animals or plants that can get along with little water, or can keep from losing the water they have, are favored—the camel and the cactus appear.

Why did this clear and simple explanation of how evolution had come about have such a startling effect on Darwin? For just this reason: that Wallace's theory was exactly the

theory that Darwin himself had arrived at. It was really one of the greatest coincidences of scientific history—two men, 10,000 miles apart, bringing the same kind of experiences to bear on the same problem, had arrived almost simultaneously at the same solution.

What happened next is a story often told. Darwin's first generous impulse was to have the Wallace paper published, and let Wallace have all the credit for the work to which Darwin himself had given the best years of his life. But Darwin's friends prevailed on him to take a less quixotic course. The solution was to present at the same time Wallace's essay together with an essay and a letter by Darwin on the same subject. This happened in June of 1858. Thus both men could receive due credit for their great achievement.

The publication of these short essays, however, did not have much influence. They were so brief and so concise that people who had not spent years on the kind of studying and observing that Darwin and Wallace had done just didn't see the point. So the next move was up to Darwin. He was the custodian of the great mass of knowledge and evidence that would convince the world. He knew what he had to do—he sat down and wrote the book we know as *The Origin of Species*. That book, which marshals an overwhelming mass of data, swept through the intellectual world like a tornado. Everybody read it, everybody talked about it. It turned the current of biological research for more than half a century, and left its mark in physics too. It blew the cobwebs out of religion and blew confusion into politics and economics and sociology and literature. And when the storm died down, man's view of himself, of his place in the universe, was changed forever.

As to Wallace himself, it is not easy to summarize the rest of his life, for he was 35 in 1858, and he still had 55 active years ahead of him. In brief, he returned to England in 1862, well-known now, married the daughter of a prominent British botanist, and settled down to a life of study and writing. He produced more than a dozen books, several of which are recognized as classics of science and travel. He was awarded the Order of Merit, Britain's highest scientific decoration, and—partly through Darwin's good offices—he was granted a pension by Queen Victoria's government.

Yet his life is an ironic story. Though he was the author of one of the salient concepts of scientific history, fate condemned him to play second fiddle to a more fortunate man. In the rest of his life, he failed to achieve the influence that one might have expected for him. There were several reasons for this, but the saddest reason is that he was too far ahead of his time.

The difficulty lay in the problem of human evolution. In the *Origin*, Darwin had avoided this touchy subject, but others took it up soon enough. If animals had evolved, then man, who is made on the same plan as animals, must have evolved too. In an excess of enthusiasm well-mixed with ignorance, many thinkers set about arranging living races of men and also of apes in what they thought was an evolutionary series—a series that started with the monkeys and proceeded up through the chimpanzee and the gorilla to the aboriginal peoples of Australia, through various African tribes to Eskimos, Polynesians, Mongols; this fanciful notion having been invented by white men from the northwest of Europe, the white man was obviously at the top. Perfectly sober and honest people in those days held views of racial superiority and inferiority that today are almost confined to South Africa. But Alfred Russell Wallace, almost alone, knew the fallacy of these views. For he was the only scientist of his time who had lived for years among native tribes, both on the Amazon and in the South Seas. He knew, for example, that tribal languages are not like the chatter of apes, as some people said, because he had learned such languages, and knew how complex they often are. He knew that primitive peoples are not mentally inferior, because he had often depended on their intelligence. He knew that so-called savages are not morally depraved, because he had trusted his life to them, and found that his trust was not misplaced.

There is a fashion in ideas, and Wallace's ideas on the essential humanity of primitive man were not particularly admired in Victorian England. But he kept on fighting—he never compromised his views—and we should be grateful to him, I think, for the more tolerant and informed spirit that is surely, if somewhat slowly, sweeping away the ignorant prejudices

of the past century. Events have proved Wallace right. And I like to reflect that he was right because he dealt with primitive people as people--not as stereotypes that fitted a theory. It was his humanity that gave him his insight into nature.

Notes on the Teaching of Evolution

ELWOOD B. EHRLE
State University College of Education, Geneseo, New York

There is probably no other single subject within the discipline of biology that has engendered as much misunderstanding and mistrust as has the subject of evolution. The mere mention of a serious discussion of this subject usually raises the tenor of interest in a roomful of beginning college biology students. Some are quite ready to hear more about a concept concerning which they have mixed emotions; some are resolute passive resisters; while others are immediately *en garde* and ready to take on all comers. Some see it as an overt attack on their religious beliefs, while others view it as a sort of mystical all-controlling demigod in itself. Since this subject is so central to the understanding of biology as a dynamic discipline, I offer these comments for consideration and criticism.

First, it is an illogical reaction of college faculty to place the blame for a muddled view of evolution on instructors in the secondary and primary school system. While there may be some measure of merit in this reaction, the main difficulties, I believe, lie elsewhere. I would expect, for example, to find very few people on the street who would be able or willing to spend time in a debate on the relative merit of isogamy vs. heterogamy. The much more intricate topic of organic evolution, however, is readily discussed not only by the man on the street, but also by well-meaning non-biology teachers, religionists of every kind, and of course, poorly prepared students. It is not my intention here to discuss the compatibility of the concept of evolution with theology, political theory, or religion. I would, however, re-emphasize to the reader that if he is a teacher of biology at any level, he has no monopoly, singly or collectively, in shaping the students' understanding of evolution.

One of the main sources of confusion can be found in a failure to separate the fact of evolution from the several theories of evolution. If one can bring a group of students to an understanding of the words, truth, proof, and fact, as they are properly used in the sciences, the statement, "Evolution is a fact," is a very defendable one. Only as we consider the fact of evolution can we hope to approach the theories constructed to explain this fact. The simple fact of evolution is embodied in the word itself. The Latin predecessor, *evolvo*, means simply to unroll, to unfold, or more simply, to change.

There are essentially two major ways in which the living world can be viewed with respect to time. It can be considered to be static, unchanging, and fixed. Species are immutable and the life that exists now is much like the life that has existed in the past and will probably continue to exist into the future. As an alternative, life can be considered to be dynamic, everchanging, and in a continuous state of development. Species are relatively plastic and transitory, and the life which existed in the past is very different from that which exists now, as well as from that which will exist in the future. The choice is not a difficult one. The entire essence of life itself bespeaks change. This change, this continuous newness of life, this unfolding, is the fact of evolution. As the biological apologists put it: "It isn't a matter of opinion, it's a matter of rocks. I didn't put those fossils in the rocks, and I do you a disservice if I try to hide them from you." Yes, it is a matter of rocks, a matter of the continuous and repeatable observation of these rocks—in short, a fact. With this understanding of a difference between the fact of evolution and the theories of evolution, the students are far more ready to consider the latter.

Second, I am of the opinion that it is an organizational error to speak of evolution before an adequate foundation in biology has been laid. Such a foundation would, of course, in-

clude a perusal of the plant and animal kingdom as a whole, as well as the intricacies of the life processes, life histories, and living habits of a series of time-honored examples. Throughout the *tour d'inspection* of the plant and animal kingdom, the extinct as well as extant groups should be discussed and displayed. Probably of prime importance among these would be trilobites and dinosaurs, both of which are extinct, as well as fossil horses, camels, and the like, whose descendents are still extant. One should not omit a presentation of the more important plant types in the life of the past—*Rhynia*, among the first known land vascular plants, *Lepidodendron* and *Sigillaria*, among the primitive spore-bearing, coal-forming trees, and, to add a touch of the bizarre, the giant horsetails which grew with them. All of this can be done without even hinting at a concept of evolution. Beginning biology students will not make the association and will approach these extinct types with as much, or, in some cases, more interest than they reveal in the extant types of life. Meanwhile, the instructor is laying his foundation.

Third, an understanding of evolution requires prerequisite knowledge of anatomy, physiology, ecology, and taxonomy. Here, as a pervading part of the presentations, should be an emphasis on similarity. Students are accustomed to thinking in terms of differences. One can experiment by asking three students to stand in front of the room and asking a fourth to describe the three. After the most obvious differences are mentioned, the more and more subtle and picayune will be described. This can go on for some time and the student offering the description will still not mention that all three have one head, two arms, one nose, etc. The theories of evolution are not built on differences between organisms but on their similarities. The fact that *Hydra* has only a loosely constructed "nerve net" and that *Planaria* has a bilobed cephalic ganglion is nowhere near as important as is the fact that they *both* have a built-in nervous system. Similarly, there is considerable difference between mice and men, but one never realizes it by looking at the plasma membranes of their cells, the metabolic activities of their mitochondria, or the *pattern* of their digestive tracts. A meaningful concept of evolution as fact must build on the tremendous similarities of seemingly very different forms of life.

Finally if you follow this outline—differentiate between the fact of evolution and the theories of evolution, give an adequate view of past life as well as present life, and continue to emphasize similarities rather than differences—the major chore is over. The various theories of evolution will then be readily understood. In my classes I choose to present only three theories of evolution: the doctrine of acquired characteristics, evolution by natural selection, and finally, twentieth century neo-darwinism, which embraces both the concepts of natural selection and those of population genetics, including hybridization, crossing barriers, isolation, and the like. By the time these are reached, the students are on the instructor's side. They are just as much in need of an explanation for the origin of the life they see as is their instructor. Unless however, the primary distinction is made between the fact of evolution and the theories which attempt to explain it, our classroom efforts help to breed more misunderstanding and mistrust than they erase.

Exposure Meter

A practical approach to exposure, through an understanding of the relationship between a photoelectric exposure meter and the grey scale, is developed in EXPOSURE METER: THEORY AND USE, a new 16mm film produced by the Indiana University Audio-Visual Center.

The 10-minute film, available in color or black and white, shows how an exposure meter works and answers basic questions concerning the intelligent use of an exposure meter in still and motion picture photography.

Prints can be rented from the usual sources or purchased from the Audio-Visual Center, Indiana University, Bloomington, Indiana. Prices are $100 for color and $50 for black and white.

Christmas Meeting

The NABT will hold its annual meeting with the American Association for the Advancement of Science in New York, December 26-30, 1960. NABT headquarters and the site of its meetings will be Hotel Roosevelt. Put this on your calendar and plan now to attend.

Darwin, Immutability, and Creation*

RICHARD P. AULIE
Bloom Township High School, Chicago Heights, Illinois

. . . could a giddy dance
of atoms lawlessly hurl'd
construct so wonderful, so wise,
so harmonized a world?
—Erasmus Darwin (1)

The doctrine of evolution is now a permanent fixture of human thought. After a hundred years of Darwin no responsible student of biology doubts that evolution has occurred, although disagreements continue as to its extent and method. It is a great watershed of science, dividing all the biology that lay before *The Origin of Species* from all that was to come.

There is very little opposition from the general public compared with the situation a few years ago. Many biology teachers would gladly attribute this to sound teaching. But we ought not to congratulate ourselves too quickly, for the lack of opposition stems not only from acceptance but also from just plain indifference. There are probably two reasons for this: (a) people come and go; they die and are succeeded by young men; old men grow weary of controversy; the young have new ideas; and there is no one sufficiently interested to carry on the argument. After all, the *Origin* was published a full century ago, and the book *per se* is rapidly becoming of interest, as a book, only to the historian of biology. Many biology teachers have not read this famous work in which the word "evolution" does not occur. (b) Then, too, people today are far more worried about what the physicists tell us about our future than what biologists say about our past. The larger problems of human existence are thus far more compelling than discovering, for example, which ancestor swam in a Silurian sea.

In any case the task of the biology teacher is much easier now for he may usually handle the theory as he likes. Let us examine the causes of the great clamor that raged over evolution not so long ago and try to understand them in a contemporary perspective.

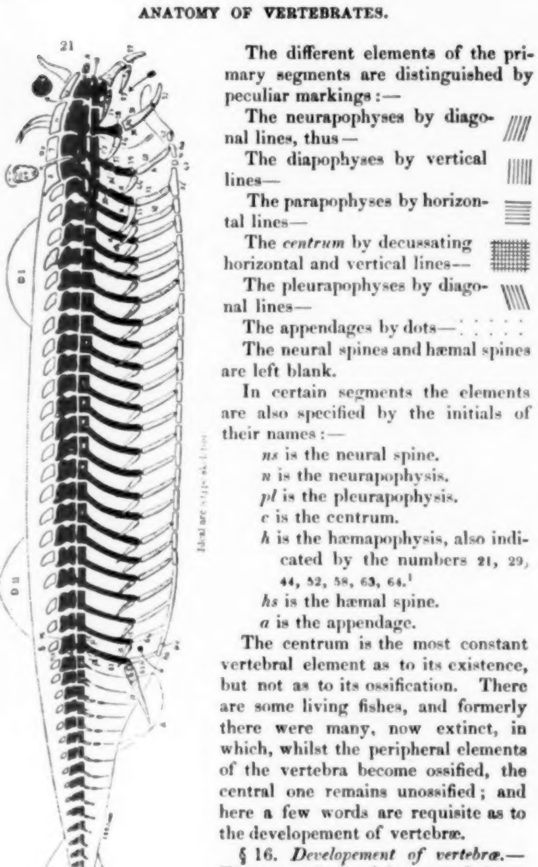
The theory of evolution was not started by Charles Darwin—the idea stirred first in early Greek minds—nor was it widely accepted before his day. Many of his distinquished predecessors such as Leclerc de Buffon (natural history), Georges Cuvier (anatomy), and Alexander von Humboldt (geology), had already observed the facts on which he based his speculations. Ideas of continuity and change had been supplied by such diverse thinkers as Aristotle (scale of life), Charles Bonnet (une échelle des êtres), Herbert Spencer (natural selection), and Charles Lyell (principle of continuity). Darwin's genius lay in bringing together the mass of facts already in existence and applying to them a simple generalization that no one had thought of before, one that has stood the test of a hundred years of biology.

Evolution replaced the idealistic and romantic biology of the 18th and 19th centuries. This highly ingenious and mystical *Naturphilosophie* was developed in England by the articulate Sir Richard Owen, renowned anatomist and paleontologist whose position in biology was displaced by Darwin. Besides replacing this old approach, evolution also opened the door to many new studies in biology. Comparative anatomy and embryology grew and flourished in the years succeeding 1859, together with whole new branches of biology such as ecology and biogeography which received their start from Darwin. In our own day many advances in genetics have come about through attempts to identify evolutionary mechanisms.

Charles Darwin was concerned chiefly with establishing *that* evolution has occurred; today biologists are concerned with showing *how* evolution has occurred, often at the sub-species level. This shift in approach is obvious to anyone at all familiar with the literature since 1859. We have only to think of the new vocabulary in use today that was unknown a century ago: adaptive radiation (Simpson), epigenetic sequences (Waddington), geographic speciation (Mayr), industrial melanism and polygenic variation (Ford), the origin of

*This paper was presented at the NABT meetings with the AIBS in Stillwater, Oklahoma, August, 1960.

life (Urey, Gaffron *et al.*), isolating mechanisms (Dobzhansky), population genetics (Sewell Wright), population explosion (Hau- *et al.*), and the inevitable DNA (Watson-Crick *et al.*).



ANATOMY OF VERTEBRATES.

The different elements of the primary segments are distinguished by peculiar markings :—

The neurapophyses by diagonal lines, thus—

The diapophyses by vertical lines—

The parapophyses by horizontal lines—

The *centrum* by decussating horizontal and vertical lines—

The pleurapophyses by diagonal lines—

The appendages by dots—

The neural spines and hæmal spines are left blank.

In certain segments the elements are also specified by the initials of their names :—

ns is the neural spine.
n is the neurapophysis.
pl is the pleurapophysis.
c is the centrum.
h is the hæmapophysis, also indicated by the numbers 21, 29, 44, 52, 58, 63, 64.[1]
hs is the hæmal spine.
a is the appendage.

The centrum is the most constant vertebral element as to its existence, but not as to its ossification. There are some living fishes, and formerly there were many, now extinct, in which, whilst the peripheral elements of the vertebra become ossified, the central one remains unossified; and here a few words are requisite as to the developement of vertebræ.

§ 16. *Developement of vertebræ.*—The central basis of the neuroskeleton is laid down in the embryo of every vertebrate animal as a more or less

[1] See 'TABLE OF SYNONYMS, Special Homologies,' for the names of the bones indicated by numbers.

Figure 1. Sir Richard Owen (1804-1892) prepared this diagram to show what he considered to be the "ideal archetype skeleton," an eternal, divine idea. All vertebrate skeletons, he maintained, are variations on this common theme. He deduced this representation from his monumental studies of vertebrate anatomy and paleontology. In his view species were also unchanging representatives of such eternal ideas or "archetypes." He also made important contributions to our knowledge of monotremes, marsupials, and anthropoid apes, and gave good definitions of analogy and homology; his biology clearly follows the tradition of Georges Cuvier. (Courtesy the John Crerar Library, Chicago.) (6)

Nineteenth century biologists were much more in the public eye than they are now. Many areas of natural history were subjects of spirited public discussion. Hardly a scientific organization would meet without some famous man from the Rayal Society taking to the lecture platform on a subject like *Megatherium*, *Archaeopteryx*, or the *theory of the skull*. On the continent Georges Cuvier and Geoffroy Saint-Hilaire quarreled publicly over two interpretations of anatomy. The celebrated controversy embittered their lifelong friendship, although Cuvier's victory had important implications for evolution. Out of this ferment on both sides of the English channel grew the opposition to Darwin that many biologists registered on purely scientific grounds. The most distinguished was Sir Richard Owen, England's foremost biologist until 1859, whose name I have already associated with *Naturphilosophie*. By contrast, his continental counterparts who were Lorenz Oken, Saint-Hilaire, and von Goethe had entertained certain evolutionary ideas. Kölliker and the aged von Baer in Germany also voiced their disapproval of the new theory.

On our side of the Atlantic, Louis Agassiz, the famed Harvard professor who had known von Humboldt and Georges Cuvier earlier in his life, vigorously denied evolution had occurred. He stoutly maintained that the idea of the common origin of man and the other primates was entirely fallacious. There was also the opposition of the clergy in England and later in America, such as the unfortunate clash between Bishop Wilberforce and Thomas Huxley. Opposition seemed to begin first among the scientists, then it soon appeared among members of the clergy, even though as I have noted most of the facts upon which evolution is based were already rather well known. Such opposition at first seems incredible to us. It spread to both sides of the Atlantic on the lecture platform, in the press, in the classroom, and in the pulpit, and lasted into the early decades of our century.

Why were Darwin's ideas resisted so vehemently? I do not think this is a puzzle, particularly if we try to understand the thinking patterns of the first half of the 19th century. There is, of course, the obvious reason that people generally are skeptical of any new idea that conflicts with established custom. Beyond this, however, the heated denials that

evolution has occurred arose primarily not from quarrels *between* religion and science, but rather because of erroneous religious themes *in* science. Darwin's book served to bring these tensions to the public consciousness.

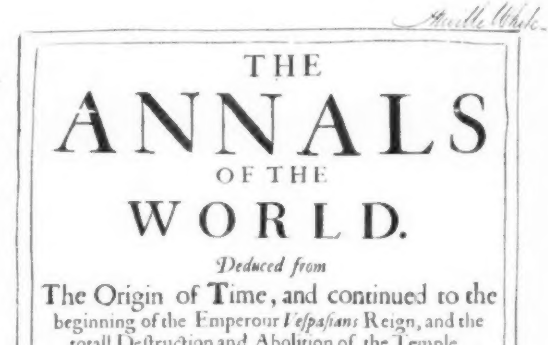
It is difficult for our contemporary minds to understand how a religious idea *in* science could have been important. This is because we usually compartmentalize our lives, carefully sealing off religious ideas from their applications to life. We too often think of religion *and* science, as though neither has a thing to do with the other. But I think the 19th century scientists aimed at a higher consistency. There is a certain logic in their method that we may admire even if they did arrive at an erroneous conclusion concerning species, as we shall see.

Many pre-Darwinian biologists were deeply exercised about the role of providence in nature and they sincerely desired to show how science supported the Bible. They thought very seriously that God had spoken *ex nihilo* once and for all in nature, that what we see around us has existed essentially unchanged since the dawn of creation, except perhaps for certain catastrophes. James Hutton's *Theory of the Earth* (1795), Robert Chambers' *Vestiges of Creation* (1844), and James Ussher's chronology in his *Annals of the World* (1658) had a wide appeal. The famous bishop had fixed the date for the creation of the world at 4004 B. C. by using too literal conclusions drawn from certain Biblical genealogies. His views were to be impugned by the geology of Georges Cuvier, Charles Lyell, and their successors who showed history is also found in the rocks, something Ussher could not have known. Biologists often have the tendency to ridicule Ussher and others who opposed evolution. However, we are never wise enough for that. They all did rather well, I think, in their context; perhaps we do not as well with what we know.

The arguments over evolution, when stripped of their nonessentials, revolved around the nature of species. Biologists were convinced species were immutable; that is, they had not changed appreciably since creation. I believe this view has had three sources in history: (a) Platonic philosophy; (b) Linnean systematics; and (c) wrong interpretations of the Bible.

Attention was directed to the concept "species" as it corresponded to an ideal, permanent type as established by divine decree, rather than to origins. Species were the unchanging category in which God expressed His wisdom. Sir Richard Owen wrote that

> ". . . the recognition of an ideal Exemplar for the Vertebrated animals proves that the knowledge of such a being as Man must have existed before Man appeared. For the Divine mind which planned the Archetype also foreknew all its modifications." (2)



THE
ANNALS
OF THE
WORLD.
Deduced from
The Origin of Time, and continued to the beginning of the Emperour Vespasians Reign, and the totall Destruction and Abolition of the Temple and Common-wealth of the Jews.
Containing the
HISTORIE
Of the OLD and NEW
TESTAMENT,
With that of the
MACCHABEES.
Also all the most Memorable Affairs of Asia and Egypt, And the Rise of the Empire of the Roman Cæsars, under C. Julius, and Octavianus.
COLLECTED
From all History, as well Sacred, as Prophane, and Methodically digested,
By the most Reverend JAMES USSHER, Arch-Bishop of ARMAGH, and Primate of IRELAND.
LONDON,
Printed by E. TYLER, for J. CROOK, at the Sign of the Ship in St. Pauls Church-yard, and for G. BEDELL, at the Middle-Temple Gate, in Fleet-Street. M. DC. LVIII.

Figure 2. We remember James Ussher (1581-1656) for his now-discredited Biblical chronology in which he suggested the actual day of creation, as seen here on page one of his book. His writings supported the claim that God had created species once and for all. (Courtesy the Newberry Library, Chicago.)

Many biologists shared his view that every living species is an inaccurate or imperfect representative of an eternal and unchanging idea. All organisms result from variations on this idea, or "archetype," a notion that may easily be traced to Plato. It is a beautiful concept that Sir Richard Owen gave biology, the "archetype," one that suggests to us profound truths that I cannot now explore, even though it is no longer useful to us.

This view, that we may trace to Plato, so unlike our modern approach, had been transmuted by the careful work of John Ray in his *Methodus plantarum* of 1644 and later by Carolus Linnaeus in his *Systema naturae* of 1735 into the immutability that Darwin demolished. (Fig. 4.) John Ray gave a classic statement of the view when he stated that

> ". . . the number of true species is fixed and limited and, as we may reasonably believe, constant and unchangeable from the first creation to the present." (3)

We should observe, however, that in later editions of the *Systema* Linnaeus was not so confident about this fixity of species.

The concept of species to which Darwin was heir was thus monotypic, defined strictly on a morphologic basis according to the early Linnean use of the term. Now we have a more plastic, synthetic, and polytypic species concept, whose populations often intergrade, and which Ernst Mayr likes to call *Rassenkreise* (4).

This static view whereby the *fact* of creation was not distinguished from the *method* of creation was further reinforced by faulty exegesis of such passages in the Bible as the early chapters of Genesis, Job 39-41, John 1, Colossians 1, and Hebrews 11. It was thought that these passages declare that God had created all species *ex nihilo* as one may now observe them. Of course, they declare nothing of the sort. Thus, the immutability or fixity of species had come to be synonymus with divine creation.

When Darwin appeared it was an easy step to the erroneous views that evolution and creation were antitheses, and that evolution, for example, would deny the reality of God and the existence of the human soul. When he showed that species were not indeed immutable it was the logical conclusion that he was also doubting providence. This troubled Darwin. In a letter to his friend, Hooker, in 1844 he expressed dismay that he was finding immutability to be false (5).

The major erroneous theme was, in short, the *"that" God has created had become inextricably linked with the "how" God created. To doubt the "how" meant also that one doubted "that" God had created.*

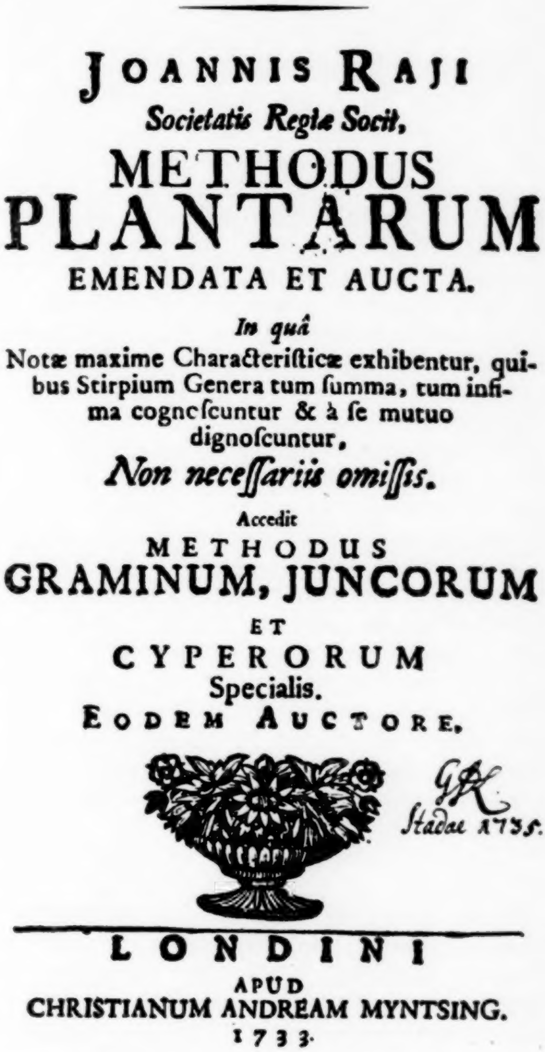

JOANNIS RAJI
Societatis Regiæ Socii,
METHODUS
PLANTARUM
EMENDATA ET AUCTA.
In quâ
Notæ maxime Characteristicæ exhibentur, quibus Stirpium Genera tum summa, tum infima cognoscuntur & à se mutuo dignoscuntur,
Non necessariis omissis.
Accedit
METHODUS
GRAMINUM, JUNCORUM
ET
CYPERORUM
Specialis.
EODEM AUCTORE.
Stadae 1735.
LONDINI
APUD
CHRISTIANUM ANDREAM MYNTSING.
1733.

Figure 3. John Ray (1627-1705), who is sometimes called the father of English natural history, was among the first to make extensive botanical collections throughout England and the continent. In his books he classified his plants alphabetically and also by the number of cotyledons. He was undoubtedly the first to attempt a scientific justification for the immutability of species. (Courtesy, the John Crerar Library, Chicago.)

In the troubled minds of many serious people to doubt the "how" meant that one was denying the validity of all religious and transcendent values. Somehow people could not grasp the idea that a natural process could be a part of a continuing creative process. Somehow creation had to be, for them, instantaneous *ex nihilo* and without any method. Even today biologists are divided on this important point. Remnants of this 19th century dichotomy—creation versus evolution—may occasionally be found in carelessly worded phrases on evolution in certain biology texts and in the utterances of well-known biologists.

For example, Sir Julian Huxley at the recent Darwin Centennial Celebration at the University of Chicago expressed the opinion "species were not created; they evolved." A century ago such a statement was a useful argument for evolution since (a) many people, including biologists and spokesmen for biologists, held that species are immutable and were created as such, and, (b) that these same individuals claimed that evolution and creation are mutually exclusive. Such a statement thus has no meaning today as an argument for evolution, for it is a hundred years out-of-date.

It is interesting, although, of course, quite pointless, to speculate on the reception evolution might have had if Darwin had employed divine providence as a background for his natural selection, not as a casual mechanism but as part of a unified, comprehensive world-life view that comes to terms with First Causes. Apparently he did not think of the idea, but then neither do many contemporary biologists.

We have indeed come a long way since Darwin. No longer are we dismayed at the prospect that today living organisms are related in time to simpler species. Furthermore, just as biological ideas become modified, theological attitudes continually change as well. Evolution provides a far more realistic and consistent view of nature than was enjoyed before Darwin's *Origin*.

Does all this mean we can go on to provide a sanction for ethics with evolutionary humanism? In other words, does the self-sufficiency observed in nature preclude an underlying providence? Many thoughtful persons, reflecting on the impact of science on human values, would reply in the affirmative. They would say science has come so far and has achieved such success that it is quite valid to build out of limited and scientific observations a total system of thought designed to explain all existence. But such a system confuses what may be observed with what is inaccessible to any sensory observation. Science for them may then become a religion.

Biology deals only with sense impressions and can make no value-judgments about ultimate causes; nor can biology assert that such issues are therefore meaningless. One simply cannot argue from natural selection to the negation of such concepts as creation, providence, and the immortality of the soul, which are nonbiological realities. Because biology is ignorant or ultimates the best adjectives we can find to describe the raw materials of evolution are "chance" and "random." But it does not follow that man is thereby an accident. Such an assertion surely does not itself flow from the scientific process. That this is so is attested by practically every philosopher of science since Immanuel Kant.

Nor can one logically defend on purely scientific grounds notions of secular progress based on evolution. This was attempted with dubious success by overenthusiastic social philosophers in the decades after Darwin. They used the theory of evolution to claim that man is getting better and better and that progress is inevitable. Those ideas perished in the rubble of two world wars, and few people talk that way anymore. However, we do find such ideas recurring occasionally in current biology literature but dressed-up in quite different language. Eminent biologists paint the future of man in generally rosy hues if only we will employ evolutionary concepts; accordingly, man's destiny is to be fulfilled only by evolution, and man himself, I suspect, ultimately becomes deified. They thus go beyond their biology. Furthermore, considering the mess we primates so often make of things—gas chambers, race riots, and atom bombs—I do not find a great deal of comfort in that line of reasoning, however charming it sounds.

Such ideas of secular progress are of a piece with 19th-century humanism and really are nothing new; they fail to account for the rich complexity and contradictions that constitute human existence and the limits of scientific abstractions in apprehending the total spectrum of truth.

Because of our dedication to science we want to learn as much as possible about our evolutionary past. At the same time we need the perspective to recognize that this knowledge does not automatically make us better human beings. Besides answering the questions *how does nature work*, and *what is it made of* –which science is teaching us to do rather well –we need also to awaken in students the recognition of the more important question, *why are we here*.

To this question biology can supply no answer. But our preoccupation with the *how* and *what* questions may lead some of us to think science thereby shows the *why* question has no validity. I think this rarely fools high school students, who are sometimes better philosophers than biology teachers. They will insist with the clear logic of the young on asking those really troublesome questions, such as "who made natural selection?" or "from where did the original hydrogen come?" They thus show us that modern biology always needs the philosopher to ask the embarrassing questions about the assumptions upon which science itself rests.

It was the genius of 19th century biology to perfect the scientific approach to the world of life and show that concepts of design and providence do not give us causal explanations. It is the failing of contemporary biology to neglect the basic philosophic assumptions which make science possible.

Many contemporary biologists are usually silent about these philosophic issues, such as, why do we assume that nature is predictable and regular; why do we claim the scientific method is valid; why do we assume that our sensory impressions give us a correct representation of the external, objective world about us. This silence is due in part to a natural reluctance to avoid erroneous conclusions of the past. But I fancy there is another, more basic reason. It is the very correct suspicion that these questions lead us right back to the concept of divine creation that so exercised the 19th century mind. I think it is no accident that the theory of evolution could appear in a civilization already suffused with the Judeo-Christian ideas that time is linear and progressive, and not cyclical, and that nature is rational and will yield its secrets to human curiosity.

I sometimes like to think–although some will find my idea disconcerting–that Darwin has unwittingly helped us perceive creation in the clear light. He unravelled the strands of evolution whereby creation and certain aspects of providence may be displayed to us. Now, if we are so disposed we may return to a fresh consideration of what the 19th Century biologist should have known, that divine creation may imply, not the method, but the purpose of human existence, and, indeed, may further suggest much of the foundation on which the edifice of modern biology securely rests.

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Talented Students

The United States can and should bring talented high school students with a special aptitude for science to the frontiers of research at a much earlier age than presently, a Ursinus College chemistry professor declared.

A way to do this has been demonstrated in an experimental four-week course in college chemistry, said Dr. Roger P. Staiger, who described the intensive program which enabled students to try for advanced placement at many colleges and universities. In this accelerated course, hand-picked 10th, 11th, and 12th grade students grasped modern chemical concepts more readily than average college students, Dr. Staiger observed. He urged that similar science programs be developed throughout the country as soon as possible.

Brownian Movement Demonstrations

FRANK E. WOLF
State Teachers College, Fitchburg, Massachusetts

Materials:

A student microscope with substage condenser and oil immersion objective; nonmotile bacteria; yeast culture; a cigarette; high powered lamp which may be focused; a "viewing chamber;" syringe and needle.

Preparation:

Construct a "viewing chamber" of three pieces of clear, transparent acetate (Tenite). The bottom piece is ¼ inch thick and 1 by 3 inches in length and width. The middle piece or chamber is 20/1000 of an inch thick and 1 by 3 inches. Bore a ½ inch hole in the center of the middle piece. (Figure 1). The top is 5/1000 of an inch thick and one by three inches.

Bond the middle piece to the bottom piece with acetone. Drill a 1/16 inch hole from the edge of the chamber to the outside of the long edge of the bottom piece. (Figure 2). Using a 3/16 inch drill, countersink the hole from the edge of the bottom piece approximately 3/16 of an inch in toward the chamber. (Figure 3). Bond the top piece to the middle piece with acetone. A veterinarian will supply a small stopper, to fit the 3/16 countersunk hole, from a vial of feline distemper vaccine. Trim the edge of the stopper to fit the viewing chamber. Buff the chamber edge opposite the stopper. After use, the chamber is cleaned by flushing with a syringe.

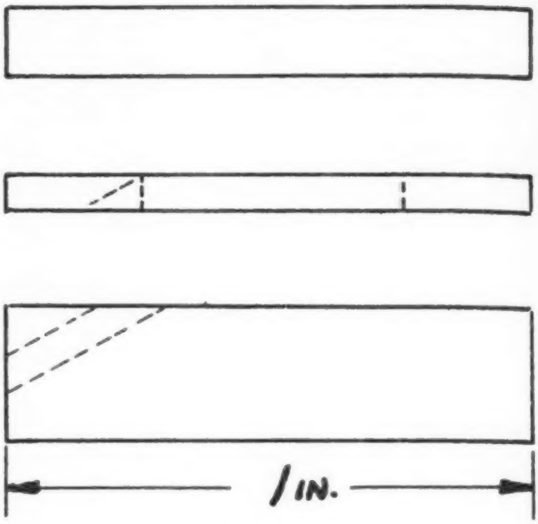

Figure 2

Procedure:

1. With the syringe, create a partial vacuum in the chamber. Fill the syringe with smoke and introduce the smoke into the chamber. This procedure has the advantage, over the open Brownian movement apparatus, of preventing the smoke from leaking out. Focus the light source from the side of the buffed edge of the chamber, using a converged beam. Using the high, dry objective, study the particles of smoke vibrating in place due to molecular bombardment.

2. Fill the chamber as before, either with

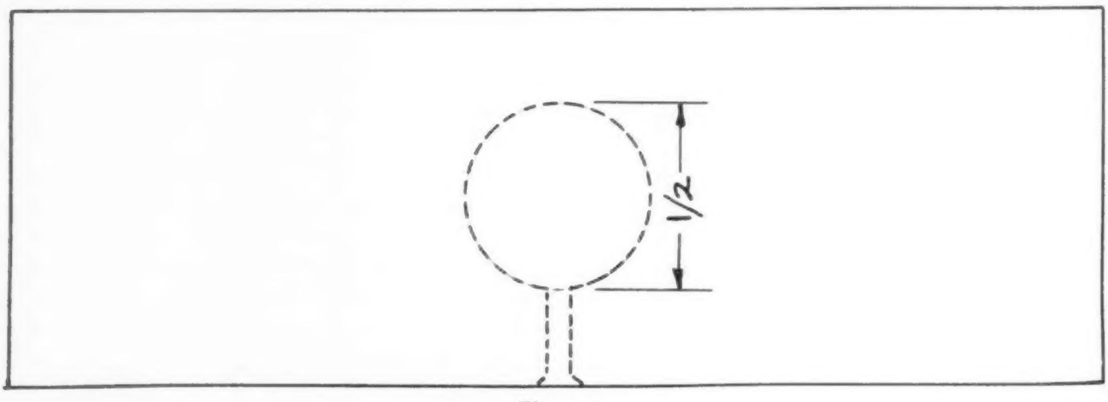

Figure 1

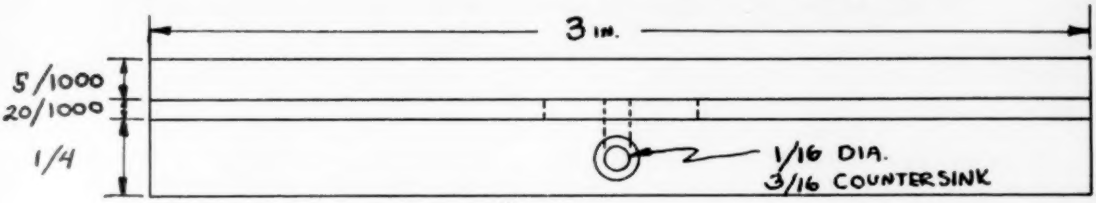

Figure 3

yeast or nonmotile bacteria, and observe the movement-in-place called Brownian movement. The viewing chamber will not leak or dry out and may be tilted for projecting directly through the tilted body tube of the microscope to a screen, without the use of an accessory bioprojector.

The bacteria may be studied under oil immersion as the top of the chamber is well within the working distance of the objective.

BIOLOGY IN THE NEWS

BROTHER H. CHARLES, F.S.C.
Saint Mary's College, Winona, Minnesota

THE TIGER IN GRANDMA'S LAP, Corey Ford, *Sports Illustrated*, September 5, 1960, pp. 68-72.

A humorous, provocative account of a serious problem—what to do about house cats which become predatory in our woods and fields.

TINY, RUTHLESS ANT WORLD, *Life*, September 5, 1960, pp. 62-72.

A series of paintings by Rudolf Freund which you will want for your bulletin board. You will want several copies for your permanent file.

ORAL POLIO VACCINE: THE BEST YET? Steven M. Spencer, *Saturday Evening Post*, July 23, 1960, pp. 20-21, 87-90.

Prevention of polio is wise. But how? An account of safe testing, or orally acquired resistance to polio, of the effects of injections of Salk vaccine and what we can expect in the near future. This is a splendid article to use in teaching scientific method.

GRANDMOTHER, WHAT SHARP TEETH YOU HAVE, Roderick Haig-Brown, *Sports Illustrated*, August 8, 1960, pp. 42-45.

The biggest pike are females, some weighing as much as five times that of the largest males. This article contains much biology learned while fishing. It could stimulate other young fishermen to make accurate observations about the fish they like to catch.

THE OVERWEIGHT CHILD, Marguerete Rittenhouse and Ruth Kamerman, *Cosmopolitan*, July 1960, pp. 74-79.

When is a child overweight? Why is a child overweight? These and other phases of the overweight problem are discussed along with methods for correcting the condition.

THE GREAT ARTHRITIS SWINDLE, Lester Davis, *Good Housekeeping*, June 1960, pp. 106, 120-124.

Thousands of people afflicted with arthritis become desperate in their efforts to relieve their condition. This summary report gives a fair idea of the worthless remedies, mechanical as well as chemical, which are being sold to cure arthritis.

THE MYSTERY OF THE FROZEN MAMMOTHS, Charles H. Hapgood, *Coronet*, September 1960, pp. 70-78.

Another theory to account for the remarkable preservation of the bodies of the mammoths.

LOOK OUT FOR SHARKS, *Life*, July 11, 1960, pp. 58-72.

Facts about sharks which swimmers at the seashore should know. Some wonderful pictures which you will want to use on your bulletin board.

THE UNSPOILED WONDERS OF A LIVING WILDERNESS, *Life*, June 27, 1960.

An excellent set of pictures of Alaskan animals and plants by Fritz Goro. You will want several copies of these for your bulletin board. Be sure to save the wonderful cover, too.

For the Science Teachers' CAREERS File

MURIEL BEUSCHLEIN
Chicago Teachers College, Chicago, Illinois

Whether you introduce the subject of careers in science as a special student project, as a separate unit, or incorporate it within the scope of the many topics you teach, the following list may include desirable items for your file. The extent of easy-to-obtain materials makes it possible for the teacher to provide sources of information and answers to the many questions on career opportunities and career requirements.

The capable science teacher, devoted to teaching his courses, and giving formal training in science to his students, also has the opportunity to inspire his most able students to investigate careers in science. Interested students have innumerable questions, some concerned with research, teaching or advanced courses, others dealing with opportunities in fields of either applied or economic aspects of science.

The following list of booklets and brochures concerned with careers in science is not as extensive as the comprehensive bibliographies and files used by guidance counselors, but because of the broad scope of career information and the ready availability of these free and inexpensive items, each teacher can establish his own CAREERS file convenient for immediate use by students or for class reference.

In most cases single copies are available free to teachers, but an occasional item may be secured in class quantities. All entries have been checked as to current availability and adequate supplies. It is recommended that teachers make their own selection and use school stationery for their requests.

American Association for Advancement of Science
1515 Massachusetts Ave.
Washington 6, D. C.
A Selected List of Career Guidance Publications.

American Association of Colleges of Pharmacy
Secretary-Treasurer
College of Pharmacy
University of Illinois
833 S. Wood Street
Chicago 12, Illinois
Shall I Study Pharmacy?

American Chemical Society
1155 Sixteenth Street, N. W.
Washington 6, D. C.
Shall I Study Chemistry, 5 cents.
The Chemical Profession, 25 cents.
Careers, $1.50 each.

American Dental Association
Council on Dental Education
222 East Superior Street
Chicago 11, Illinois
Careers in Dental Hygiene, 12 p.
Careers in Dentistry, 20 p.
Dental Hygiene Aptitude Testing Program

American Dietetic Association
620 N. Michigan Avenue
Chicago 11, Illinois
Dietetics as a Profession
A Dietetic Internship
The Future Is Bright
Chart Your Course Toward Dietetics
Dietetics in Demand
Single copies free to teachers and librarians—25 cents to students.

American Fisheries Society
P. O. Box 429
McLean, Virginia
Fisheries as a Profession

American Geological Institute
2101 Constitution Avenue, N. W.
Washington 25, D. C.
Shall I Study Geological Sciences? Single copy free; 10 cents per copy in quantity.
Why Study Geology—Covering Old and New Ground, Careers in Exploration Geophysics, Careers in the Mineral Industries, Single copy free, 5 cents in bulk.
Careers in Geophysics and Geochemistry, $1.00.

American Heart Association
44 E. 23rd Street
New York 10, N. Y.
Decision for Research. Write to your local chapter for booklet and film series.

The American Museum—Hayden Planetarium
Career Brochure
81st at Central Park West
New York 24, N. Y.
A Career in Astronomy. Send stamped addressed 4½ x 9½ envelope.

American Institute of Electrical Engineers
33 West 39th Street
New York 18, N. Y.
The Indispensable Man, Your Career as an Engineer in Aviation.

American Institute of Physics
335 E. 45th Street
New York 17, N. Y.
Physics as a Career, Should You Be a Scientist? List

of Colleges and Universities Offering Physics Majors.

American Optometric Association
4030 Chouteau Avenue
St. Louis 10, Missouri
What Is an Optometrist?
Your Eyes and Optometry
Monograph on Optometry

American Osteopathic Association
212 E. Ohio St.
Chicago 11, Illinois
The Osteopathic Profession and Its College
A Guidance Leaflet, Osteopathy
Osteopathic Education, reprint of the annual January issue of the *Journal of the Osteopathic Association*

American Personnel and Guidance Association
1605 New Hampshire Avenue, N. W.
Washington 9, D. C.
How To Create Your Career, 1-25 copies (30 cents per copy), 26-100 (25 cents per copy), 100 & over (20 cents per copy).
NVGA Bibliography of Current Occupational Literature, 1959 revision, $1.00 per copy.

American Public Health Association
1790 Broadway
New York 19, N. Y.
Public Health—A Career With a Future, 25 cents.

American Society of Agronomy
2702 Monroe Street
Madison 5, Wisconsin
What Is an Agronomist?

American Society of Civil Engineers
33 W. 39th Street
New York 18, N. Y.
Your Future in Civil Engineering

American Society for Horticultural Science
Department of Horticulture
Michigan State University
East Lansing, Michigan
Horticulture—A Challenging Career

American Society for Metals
Metals Park
Novelty, Ohio
Your Career in the Metallurgical Profession, 95 p.

American Society of Plant Physiologists
Dr. G. Ray Noggle
Department of Botany
University of Florida
Gainesville, Florida
Plant Physiology as a Career

American Society of X-Ray Technicians
16 Fourteenth Street
Fond Du Lac, Wisconsin
Your Career in X-Ray

American Society of Zoologists
Dr. Gairdner B. Moment
Department of Biology
Goucher College
Baltimore 4, Maryland
Careers in Animal Biology

American Veterinary Medical Association
600 South Michigan Avenue
Chicago, Illinois
Veterinary Medicine as a Career, one copy free, additional copies 10 cents each.

The Aircraft Industries Association
610 Shoreham Building
Washington, D. C.
Career Opportunities in the Aircraft Industry

Air Transport Association of America
1107 Sixteenth Street, N. W.
Washington, D. C.
Career Opportunities with the Airlines

Allied Chemical Corporation
P. O. Box 271
Syracuse 1, N. Y.
Your Career in the Chemical Industry

Atomic Industrial Forum
3 East 54th Street
New York 22, N. Y.
Youth's Opportunities in the Atomic Industry, 40 p.

Bios Vocational Series
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P. O. Box 515
Ansonia Station
New York 23, N. Y.
Physical Therapy as a Career, 25 cents.
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The Medical Record Librarian, 25 cents.
A Career in Hospital Administration, 25 cents.
Plant Science as a Profession, 25 cents.
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Butterworth Hospital
Grand Rapids 3, Michigan
Hospital Careers.

Canadian Committee on Counselling in Engineering and Science
18 Rideau Street
Ottawa 2, Ontario
After High School What?
Your Career as a Chemist
Your Career in Chemical Engineering

Career Publications
Largo, Florida
For Science Students Only, 15 cents.
Employment Outlook for Biological Scientists

Case Institute of Technology
Cleveland, Ohio
Chemistry and Chemical Engineering

Chamber of Commerce of the United States
Education Department
1615 H Street, N. W.
Washington 6, D. C.
Education—An Investment in People, 44 p., $1.00.
How to Plan Career Conferences for Teen-Agers, 22 p., 40 cents.

Committee on Careers in Nursing
2 Park Avenue
New York 16, N. Y.
Janie's Decision
Fact Sheet
Women with a Future

Curtis Publishing Company
Educational Bureau
Independence Square
Philadelphia 5, Pennsylvania
The Job They'll Never Finish—reprint from The *Saturday Evening Post* on map making, available in class quantities.

Detroit Institute of Technology
College of Pharmacy
2020 Witherall Street
Detroit 26, Michigan
Your Opportunities in Pharmacy

Engineers' Council for Professional Development
29-33 W. 39th Street
New York 18, N. Y.
Engineering a Creative Profession, 25 cents per copy, 50 or more, 40% discount.

Entomological Society of America
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Career Opportunities in Biology, by N. B. Stevens, NAS-NRC Pub 552, 63 p. Washington, D. C., 1957. $1.00.

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What's in Your Future—A Career in Health? 25 cents. Public Affairs Pamphlet #281.

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Careers in Industrial Chemistry, no charge for single copies.

Scholastic Magazines
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Science World, Including Tomorrow's Scientists, published 16 times a year, subscriptions $1.50 per year.

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Your Future in Science. By Morris Meister and Paul Brandwein, 1958, 60 cents.
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How to Get into Science and Engineering, 10 cents. A leaflet published by Science Service to inspire and inform students interested in scientific careers, tips for the high school students, necessary prerequisites, how to do a science project, career possibilities. Postpaid 100 copies for $3.00.

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Washington, D. C.
Career Service Opportunities in the USDA, Agriculture Handbook #45. 50 cents from Superintendent of Documents.

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Soil Conservation Service
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Careers in Soil Conservation Service, #717
A Soil Science Career for You in Soil Conservation

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An Engineering Career for You in Soil Conservation Service, #715

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Early American Soil Conservationists, Misc. Pub. 449.

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U. S. Department of Interior
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Careers in the United States Department of the Interior, 1957. Copies may be obtained from the Government Printing Office, Washington 25, D. C., 25 cents each.

U. S. Department of Labor
Washington 25, D. C.
Employment Outlook in the Biological Sciences. Bulletin No. 1215-5, 1957, 15 cents.

U. S. Department of Labor
Women's Bureau
Washington 25, D. C.
Professional Engineering—Employment Opportunities for Women, Bulletin 254, 20 cents.

Employment Opportunities for Women Mathematicians and Statisticians, Bulletin 262, 25 cents.

Is "Math" in the Stars for You? Leaflet 28.

Employment Opportunities for Women in Selected Scientific Fields

Outlook for Women in Occupations Related to Science, Bul. 223-8

Outlook for Women in Science, 223-1-204, 15 cents.

United States Department of Labor
James P. Mitchell, Secretary
Bureau of Apprenticeship and Training
Washington, D. C.
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College Biology Teachers

The Association of Midwestern College Biology Teachers will hold its fourth annual meeting at Mankato State College, Mankato, Minnesota, on October 21-22, 1960. Any teacher of the biological sciences in a college or university located in a midwestern state is invited to become a member and attend the meetings. Membership dues are $2.00, payable at the meeting, or to the Secretary-Treasurer. Information and reservations for this year's meeting may be obtained by writing Dr. LaRoy Zell at Mankato State College.

The Association, founded at Drake University in 1957, has a membership of about 300 college and university teachers of biological sciences. Its purpose is to further the teaching of biological sciences at college and other levels of educational experiences; to bring to light common problems involving biological curricula at the college level by the free exchange of ideas in the endeavor to resolve these problems; to promote research by both teachers and students; and to create a voice which will be effective in bringing the collective views of college biology teachers to college and civil government administrations.

Officers for the current year are Ted F. Andrews, Kansas State Teachers College, Emporia, President; William K. Stephenson, Earlham College, 1st Vice-President; LaRoy Zell, Mankato State College, 2nd Vice-President; and John M. Hamilton, Park College, Secretary-Treasurer.

Leaflets

The National Committee for Natural Areas for Schools have published the following leaflets: "The Site for the New School," "Indoor Equipment for Outdoor Education at Schools," "A School-Grounds Plant Exhibit," "Checklist of Educational Environments Desirable on School-Controlled Property."

The leaflets are available from John W. Brainerd, Springfield College, Springfield, Mass.

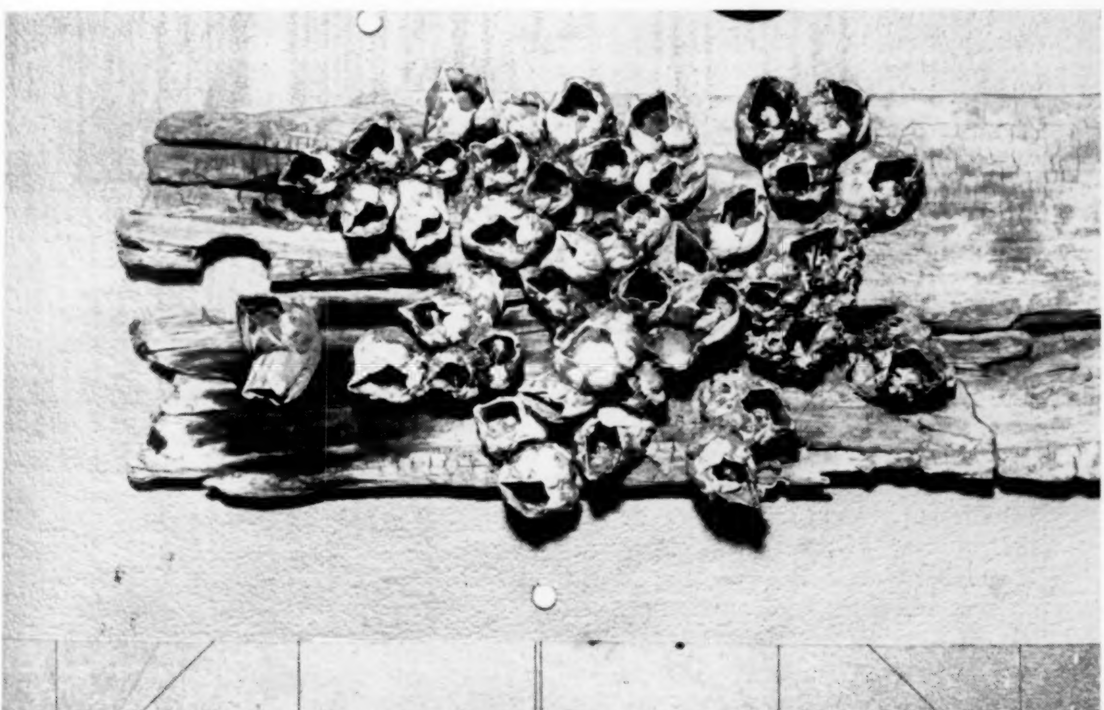
Barnacles in Fact and Fiction

JOSEPH L. PARKHURST, JR.
Colonia, New Jersey

The dictionary might be considered a likely place to introduce readers to the word *barnacle*, usually defined as a type of marine crustacean, and sometimes as a persistent hanger-on. It comes from the French *bernicle*, meaning wild goose, and refers to a medieval belief, held through the Seventeenth Century, that goslings were hatched from the barnacle-like fruit of trees. Probably this legendary "barnacle tree" was an old waterlogged branch washed ashore and covered with hundreds of little white shells. In the eyes of the early naturalists these shells appeared to be stuck on like acorns to an oak tree suggesting the name sea-acorns.

Another fictitious story about barnacles was told by a traveler of the Middle Ages, Sir John Mandeville, supposed to be the author of a popular book of adventures and marvels. His narrative includes an account of some sort of tree in the Far East whose ripened fruit cut in two revealed baby lambs.

Georges Cuvier, the eminent professor of comparative anatomy in Napoleonic times, classified the barnacles as mollusks, and kept them in that tribe in spite of new disclosures. By making a study of plankton and the life histories of its members biologists found that the barnacle was really a close relative of the crab. A few lines from "Life, in its Lower, Intermediate, and Higher Forms," by the mid-Victorian naturalist, Philip Henry Gosse, explain the closing moments of the barnacle's embryonic life in the sea drift. "In this stage the little animal searches about for some suitable spot for permanent residence; a ship's bottom, a piece of floating timber, the back of a whale or turtle, or the solid rock. When its selection is made, the two antennae, which project from the shell, pour out a glutinous gum or cement, which hardens in water, and firmly attaches them. Henceforth the animal



Ivory barnacles, *Balanus eburneus*

is a fixture, glued by the front of its head to its support."

Thick plates of lime fit together like a tent around each acorn-shell, with a hinged lid at the top, protecting them from the heaviest surf. Noting the characteristic feathery legs hidden under this lid, barnacles as a group are called *Cirripedia*, using these appendages to sweep food particles from the water. This fishing activity is sketched poetically in a little book by Celia Thaxter, who spent much of her life on the Isles of Shoals, off Portsmouth, New Hampshire. "At the water's edge one finds the long ledges covered with barnacles, and from each rough shell a tiny, brown, filmy hand is thrust out, opening and shutting in gladness beneath the coming tide, feeling the freshness of the flowing water."

Barnacles are probably best known as fouling agents on ships' bottoms, and the latter are sent into dry dock periodically to be scraped clean. In his handy guide, "Common Objects of the Sea-Shore," the Rev. J. G. Wood comments on these ship mates below the water line. "These creatures are often found clinging in great numbers to the bottoms and keels of vessels, sometimes interfering with their speed. Their growth is very rapid, and it has often happened that a ship has started upon a short voyage without a single barnacle adhering to her planks, and yet has come back encumbered with a whole army of them."

If there is one distinction the barnacles have it is the attention they received from the world famous naturalist, Charles Darwin. Over a period of several years he made an exhaustive study of the whole group, including many specimens brought back from his globe-circling voyage in H. M. S. "Beagle." After Darwin, barnacles were no longer regarded as one of the ocean's unsolved mysteries but they remain an absorbing subject for beginners.

Eye Pigments

The common housefly may help to explain how our eyes are able to distinguish colors. A yellow pigment has been isolated from the eyes of houseflies, and its use in research is expected to bring forth new facts about the light-sensitive pigments that make color vision possible, according to Dr. J. M. Bowness, biochemist in the Biophysical Research Laboratory of the University of Pittsburgh Eye and Ear Hospital. Such research may ultimately lead to a better understanding of color blindness, he added.

A few light-sensitive pigments have been found in the human eye and in the eyes of chickens, honey bees, and cattle, Dr. Bowness said, but they have all been red, blue, or purple. It has been impossible to explain the sensitivity of human beings, animals, and insects to different colors (different wavelengths of light) in terms of these visual pigments.

The yellow pigment, however, ties in with the fact that insects are known to be attracted by light of considerably shorter wavelength than is visible to human beings.

Vision is thought to depend upon the presence in the eye of pigments that are changed chemically when light falls upon them, the speaker explained. The fact that they differ in color indicates that they absorb light of different wavelengths. It has been observed that in human beings the eye is stimulated by wavelengths ranging from 390 to 700 millimicrons (a millimicron is less than a twenty-millionth of an inch). The human eye, however, is less responsive to light near the extreme violet and red ends of the spectrum than to light in the center. Insects are attracted by light with considerably short wavelengths, averaging about 360 millimicrons.

Dr. Bowness pointed out that several visual pigments have been identified, including rhodopsin—responsible for night vision—and iodopsin—thought to aid daylight color vision. But not enough have been found yet to account for the differences among various animals or to provide a factual basis for some of the theories of color vision.

Microbiology Issue

The June, 1960, issue of ABT has been an overwhelming success if requests for issues are any criterion. Extra copies may be obtained from Executive Secretary, American Society of Bacteriologists, 19875 Mack Avenue, Detroit 36, Michigan.

Xenopus laevis: An Excellent Laboratory Animal

WAYNE WESTMARK
Florida State University, Tallahassee

The search for suitable laboratory animals has plagued high school biology teachers for many years. The selection of an interesting as well as a useful demonstration animal presents even more of a problem. The indispensable laboratory animal such as the leopard frog and the salamander are used in most all biology and physiology classes. Even to the more sophisticated biologist the beauty of these animals is never lost. However, the student may become bored with seeing these routine laboratory animals every day. One way of solving such a problem is to bring to the lab interesting specimens, a very good example of which is the tadpole of the *Xenopus laevis*, or the South African clawed toad.

The tadpoles are entirely transparent except for a few random chromatophores on the dorsal part of the body. As the animal grows larger and progresses towards metamorphosis, the chromatophores become more numerous and eventually cover the entire animal.

Figure 1. Dorsal view of mature tadpole.

The transparency of the animal is a feature that is invaluable in studying its anatomy and morphology. All the organs of the head and some of the organs of the trunk can be viewed by placing the animal in a half-filled petri dish and putting it under a binocular dissecting microscope. This gives the student the opportunity to study the organs at any time as well as to make an over-all study of metamorphosis.

Of particular interest are the heart, eye (optic nerves), otic capsule, chromatophores, and the circulatory system. All of these structures are clearly visible under a dissecting microscope.

This animal is quite adaptable to laboratory conditions and requires only a small amount of care. The adult frog is strictly carnivorous, feeds only while in the water and is entirely aquatic. The frog gets its name from the fact that it has clawed toes; it has neither teeth nor tongue.

The frogs may be kept in a small, square or round aquarium with several inches of water. They may be fed a variety of things such as ground beef, beef liver, beef kidney, and pork kidney, and should be fed once or twice a week. The water should be changed in the aquarium 12-24 hours after each feeding to prevent fouling of the water.

In its natural habitat the male frog stimulates the female frog in the early spring. However, these animals can be bred successfully in captivity with high yields of eggs throughout the year. The female is injected with 400-600 units of chorionic gonadotrophin and the male with 200-300 units. For best results the needle should be inserted just under the skin on the posterior dorsal part of the hind leg and passed cephalad just anterior to the cloacal opening. Inject the gonadotrophin into the lymph sac and place the animals back in the water to spawn. In 6-8 hours the egg laying should be at its maximum. After the spawning is completed, remove the eggs to fresh clean water. Within five days the young

Figure 2. Dorsal view of various stages of metamorphosis of the tadpoles.

tadpoles should be free swimming larvae.

At this stage they are ready to begin feeding. It is interesting to observe that within an hour after food has been added to the aquarium, the animals begin to surface and take gulps of air. This marks the point at which they start using their lungs.

As the tadpoles feed, they assume a diagonal position in the water. This "head down" position is due to the extra large head of the tadpole making them "front heavy." To counterbalance this unequal distribution of weight, the tadpole maintains a constant, rapid whiplike motion of the extreme tip of the tail. This prevents the animal from sinking head first to the bottom of the aquarium. This whip-like motion of the tip of the tail is not to be confused with the undulating movements of the entire tail which propel him through the water.

Liver powder is the best food to use for these animals since it can be purchased ready to use. Unless the tadpoles are overcrowded, 1 mg. of liver powder per animal per day is sufficient for normal growth. If the aquarium becomes fouled due to excess food, the amount will have to be lessened. The water should never need changing if the proper food intake is maintained.

Salt Water

A new laboratory machine that can split the salt and essential minerals from sea water —and that may make possible a multiple vaccine against communicable diseases—has been described. The "spectrolator," as the machine is called, separates mixtures of substances by means of combined chemical and electrical methods, Dr. Arthur Karler, chemist and biophysicist, of the Karler Laboratories, Berkeley, Calif., said.

"It actually splits up various substances into component fractions somewhat as a glass prism separates white light into its characteristic spectrum of rainbow colors," Dr. Karler explained. The main part of the apparatus is a filter paper curtain, he said. A solution is fed in at the top, and a continuous direct electrical current passes across the fluid as it runs down the curtain. The degree of separation of the fluid components is governed by the electrical voltage and the speed at which the fluid is fed.

"Each component builds up its own path through the curtain, to be collected in a purified state at its respective position across the curtain," Dr. Kaler said. "As as example, if ocean water is processed, the yield would be pure water at a center drip point, with negative and positive ions (charged fractions of the mineral molecules) on either side. With greater separation, pure water is collected at the center; sodium calcium and magnesium hydroxides are collected on one side, and chlorine and bromine gases and certain acids on the other. Thus the spectrolator makes possible, simultaneously with salt water conversion, the extraction of the many essential minerals present in unlimited supply in ocean water.

Science Encyclopedia

The McGraw-Hill Book Company announced that it has finished and sent to the printer the manuscript of the largest technical publication ever undertaken in the English language—an *Encyclopedia of Science and Technology.*

The work will be published in fifteen large volumes this fall and will contain 7,224 articles written by some 2,000 authorities on their respective subjects. The work of these contributors was guided by a large corps of consulting editors, each a specialist in one of 62 assigned fields of mathematics, engineering, physical science, life science, earth science, agriculture, conservation, meteorology, space technology, etc.

BOOK REVIEWS

ZULU JOURNAL, Raymond B. Cowles, 267 pp., $6.00, University of California Press, Berkeley, California, 1959.

This is a book which I think every biologist should read. Professor Cowles, Professor of Zoology at the University of California, Los Angeles, is an active conservationist and has served as consultant to Walt Disney on *The Living Desert* and to *Life* magazine. In this book he recounts his observations in Natal, a little country on the east coast of Africa. From there he was hurried away to school in the United States in the early 1900's, leaving him with memories of a primitive Africa already undergoing profound ecological change. He returned in 1925-27 and again in 1953. The result is this book.

"These old men of the Zulu love to reminisce over their beer pots, but their memories are fading fast," says Professor Cowles. "In most native reserves these men tell of the days when the Zulu *impi* (armies) ranged abroad ravishing the country and keeping population down. In those days the bush was abundant in the valleys, and between the bush and on the highlands, *etafeni*, there were miles of tall grasses rippling in the breeze and swarming with game. There was more than enough grazing for the wild and domesticated animals, and the ranges were never overgrazed." But, he continues, "The multitudes consume the crops and then, from dire necessity, destroy the land from which they get their sustenance. And yet we speak of man's conquest of nature as though it were an unmitigated blessing, and our statesmen and politicians with no recognition of population growth, carelessly speak in one breath of both eliminating disease and raising the standard of living of the world. Without victory over man's careless irresponsibility for his reproduction, we can never achieve the millennium that has been so nearly within our grasp, but instead fumblingly and ignorantly, we may go down to defeat."

Reminiscence is always hard on the reader when he has shared the same experiences as the writer even though they be a hemisphere apart. And everyone born before 1920 has shared some of Professor Cowles' experiences if he has eyes to see the changing natural world about him. Here on this page one dies a little with the vanishing game, but there on another he relives some brilliant moment of pure beauty. Between these extremes are some fascinating insights into natural history and the ecology of man. This is a thinking man's book, but it is, perhaps unfortunately, not very well filtered for the tender minded who want to see only the beauty of nature and let the rest go.

One of the many original ideas which Professor Cowles presents is the startling hypothesis that the black skin of the African is actually concealing coloration in nature. Against the natural background of bush forest, the blacks are only dimly perceptible, just as the striped zebra tend to disappear against a distant landscape. Civilization has unmercifully reversed the situation for the blacks.

Africa is profligate of life. Professor Cowles describes in detail the great flights of winged termites which leave the nests to mate and found new colonies. These eruptions occur over vast areas, where through the activities of many species of termites the woody condiments of plant growth are converted into edible proteins, carbohydrates, and fats to be flung back into the ecosystem by the mating flights. Man, beasts, and birds gather to partake of the tasty feast—today, perhaps even more than in the past, for "rocks are sprouting" where Zulus plant their fields.

"With a crescendo of painful realization," Professor Cowles concludes, "I perceived more sharply than before that without first solving the problems of man, most forms of plant and animal life of this fair land would in due time be destroyed forever; and that beyond the bounds of South Africa, almost everywhere on our globe, man's uncontrolled increases in numbers will threaten all forms, although a few adaptable species may locally survive." Let us hope that among the adaptable species will be man.

Frank N. Young, *Indiana University*

BIOLOGY, Kroeber, Wolff, Weaver, 646 pp., D. C. Heath and Company, Boston, Mass., 1960.

This is the revised 1960 edition of the textbook which appeared in 1957. The cover has been changed to a more subdued art work from the earlier edition, but the illustrations in the 1960 version are rather remarkable. There is an abundant use of color photographs, and most of the illustrations are new and the reviewer has not seen them in other textbooks.

The outline of the book follows a traditional approach similar to one of the other best sellers in the high school biology textbook field. Perhaps a listing of the units would be helpful to understand this point. They are: How Living Things Are Alike; The Many Kinds of Plants and Animals; Plants, The World's Food Makers; How Our Bodies Work; Why We Behave As We Do; Bacteria and Health; Reproduction; Heredity and Environment; The History of Living Things; Conservation; and Radiation and Space Biology.

There are several unusual treatments in the book which deserve special notice. The signs of

the times are evident in the unit consisting of a chapter on radiation biology and one on space biology. The radiation biology is chiefly taken up with the treatment of how isotopes are used in biological research. Radiation effects on living cells are treated also at some length. Diagrams of atoms are used to illustrate the meaning of isotopic forms. The space biology chapter concerns effects of acceleration and G, as well as the psychological effects that might be anticipated in such travel.

Still another unusual treatment in the book is a series of field trip guides, beautifully illustrated, at the beginning of the book which, of course, can be used at the teacher's discretion. They are excellent introductions to field trips, giving the students specific directions as to what to look for and how to look for them.

The treatment of structures of traditional organisms used in high school biology is reserved for the appendix. Here the traditional diagrams are located giving the parts of the animals as well as dissected views.

One of the disturbing points in most high school biology books is the treatment of the concept of evolution. While there is a full treatment of this topic, the word is used rarely in the treatment, but at least it can be said that it is used. DNA is described in several places in the text, but the equating of DNA and the gene is a point upon which the authors will probably be able to stir up a real argument with many professional geneticists. While the treatment of photosynthesis is advertised as being modern and up to date, it is indeed sketchy. The traditional formula for photosynthesis is still used, but the text includes the idea that energy with chlorophyll is used to split water molecules. This concept seems to be missing in many of the traditional high school biology books.

There is an abundance of information in the book which should be of real benefit to both students and teachers. Early in the book there are hints on how to study the course as well as this specific book. Chapter-end materials include vocabulary drills, test questions, project ideas, and extra reading materials.

There is an extensive treatment of human health problems, and microbiology is centered in this particular unit. This is rather unfortunate, primarily because the bacteriology material is tied up with pathogenic forms chiefly.

This new text is fairly illustrative of the new types of high school biology textbooks that have appeared within the last five years. They are handsomely and profusely illustrated, the arrangement of the textual materials is rather traditional, and a great effort is made to tie in some of the new ideas and materials from biological research. Also, there is a minimal treatment of the physical basis of biology, but there seems to be a strong assumption that much of the molecular view of matter has been taken up in previous courses. The publishers indicate that the reading level of the book is from grades 8.5-9. All in all, this is a worthy addition to the extensive group of high school biology texts that are now on the market. It should be consulted most thoroughly for possible use.

P.K.

LABORATORY GUIDE IN PLANT ANATOMY, Katherine Esau, 32 pp., $.75, John Wiley & Sons, Inc., New York, New York, 1960.

This inexpensive lab manual is designed primarily to be used with the author's ANATOMY OF SEED PLANTS and should prove quite satisfactory for courses in plant anatomy. For most of the exercises several choices of plant material are indicated so that teachers should have no difficulty in finding material to illustrate the various topics.

Charles B. Heiser, Jr., *Indiana University*

BIOCHEMISTRY OF STEROIDS, Erich Heftmann, Erich Mosettig, 231 pp., $6.90, Reinhold Publishing Corporation, New York, 1960.

This book treats in a clear and concise manner an area which otherwise can only be studied by reading numerous reviews, books, and articles. The manner of presentation, together with the generous use of structural formulae, will be of great value for the many students, research workers and teachers in biochemistry, physiology, endocrinology, and pharmacology. The book should also appeal to the biology teacher, not only because of its timeliness, but because it touches upon many fascinating areas. The extensive bibliography is helpful for those who want to become more acquainted with special aspects of the steroids. The price of the book is not excessive.

Willem van Wagtendonk, *Indiana University*

THE RUSTY LIZARD, W. Frank Blair, 185 pp., $4.50, University of Texas Press, Austin, Texas, 1960.

This book should be of value to the biology teacher, not only for the results of the special study which it presents but also as the source of many ideas concerning field activities. The rusty lizard, *Sceloporus olivaceus*, is a relative of the common eastern *Sceloporus undulatus* or fence swift. The latter in the East and many other species of the genus in the West and Southwest can be studied profitably using Dr. Blair's methods by anyone with a little equipment and lots of patience.

Dr. Blair, his wife, and a group of graduate students marked and observed over 3000 individual lizards in the population on a 10-acre plot of eroded river terrace near Austin, Texas. Nearly every aspect of biology was considered. Food, predators, temperature relationships, growth, reproduction, and social activities are a few of the subjects on which detailed observations were made.

The results of this study are significant for many aspects of ecology. Dr. Blair concludes that the lizard population on the area is a dynamic system, adapted to and adjusting to the pressure of the environment in which it occurs. The "rusties" are an important link in the local food chain; they represent the primary converters of small insects into larger food packets and thus support numerous birds, mammals, and other reptiles. The sum total represents one of the most complete reports available on the ecology of any lizard.

The writing, printing, and illustrations are all of the highest quality. Since I once narrowly missed shooting Dr. Blair, I would be ungracious not to give his book favorable notice. It does not, however, need any concession. Its excellence is evident from introduction to conclusion.

Frank N. Young, *Indiana University*

STUDY GUIDE AND WORKBOOK FOR GENETICS, Irwin H. Herskowitz, 274 pp., McGraw-Hill Book Company, Inc., New York, 1960.

A fine book of lecture notes, bibliographic references, questions and problems, and periodic examinations based on a televised course financed by the Fund for the Advancement of Education. Lectures are by such outstanding geneticists as L. C. Dunn, R. E. Cleland, E. Altenburg, Jack Schultz, J. F. Crow, C. Stern, G. W. Beadle, H. J. Muller, Th. Dobzhansky, G. L. Stebbins, T. M. Sonneborn, E. B. Lewis, R. A. Brink, J. D. Watson, and J. Lederberg. Some of the questions are based on the televised lecture and are not readily answered from these notes, but they are provocative and real problems for the student. Illustrations aid the explanation of the concepts which start with very simple Mendelian laws to the origin of life. It is an unusual treat for teachers and students to see between the covers of one book the compiled wisdom of these geneticists. Highly recommended.

P.K.

SCIENCE AND LIBERAL EDUCATION, Bentley Glass, 115 pp., $3.00, Louisiana State University Press, Baton Rouge, La., 1959.

Three seemingly unrelated essays which do have relationships are here presented by a distinguished biologist. The first essay, one of three given as lectures, takes up the significance of genetics in modern history and points clear implications for the future of man. The improvement of man through genetics is given extensive treatment. The third essay also deals with genetics but primarily from its evolutionary and ethical significance for the future of man. More questions are asked than answered, but it is important to have them asked at this time. Sometimes the complexities of philosophical terms seem to get in the way of the essay's development, but they are probably necessary to get things underway.

It is the second essay which hits hard a theme which will probably receive greater emphasis in the future. It has been pointed out before, as the author shows, but it needs the added punch of this work. The theme is simply that science is the core of a liberal education and must be taught in this way. This is not to relegate all other subjects to a secondary role, but it is to point out how consistently they have ignored the progress and importance of science. After all, science embodies the most important facet of a liberal education, freedom of the mind which comes from the pursuit of truth, and it *must* be made the basis of a liberal education in a modern sense. The academician and professional person in other fields is not truly educated until he sees and appreciates modern science. Science teachers have much work to do.

P.K.

EVOLUTION ABOVE THE SPECIES LEVEL, Bernard Rensch, 419 pp., $10.00, Columbia University Press, New York, New York, 1960.

This thoughtful book presents a consideration of evolution as a multiple rather than a single process. Dr. Rensch believes that macroevolution, like mutation, is basically undirected. Persistent selection and constant correlations may encourage the emergence of certain trends. This book also reviews the evolution of psychic phenomena, parallel to the phylogenetic development of nerve centers and sense organs. The book is devoted to a detailed study of evolution above the species level. It is a well written and thoughtful book.

C. J. Goodnight, *Purdue University*

INTRODUCTION TO FOODS AND NUTRITION, Gladys Stevenson and Cora Miller, 517 pp., $6.25, John Wiley & Sons, Inc., New York, 1960.

Designed for a one-semester college course in nutrition in home economics. The first chapter concerns itself with a cursory summary of the biology of food while the rest of the book is devoted all the way from food preparation to the Pure Food and Drug Act. The introduction begins with the problem of food in space travel.

P.K.

TRUDY-MARINE BIOLOGY, B. N. Nikitin, 302 pp., American Institute of Biological Sciences, Washington, D. C., 1959.

This is a translation of The Transactions of The Institute of Oceanology, U.S.S.R., Vol. XX. There are thirteen articles, all technical reports of interest to specialists but unlikely to be of interest to the general biologist.

Sears Crowell, *Indiana University*

HISTOLOGICAL AND HISTOCHEMICAL TECHNICS, Harold A. Davenport, 401 pp., W. B. Saunders Company, Philadelphia, Pa., 1960.

A new microtechnique manual which biology teachers should examine for inclusion on the reference shelf. There are a few introductory chapters and then succeeding chapters take up the extensive knowledge and techniques used in the major steps involved in preparing materials for microscopic examination. They are: fixation; washing, dehydrating, and clearing; embedding; equipment for sectioning; technique of sectioning; mounting and covering; and staining. There are other sections on fixing and staining formulae, and techniques involved. The concluding section is on histochemistry, indicating the techniques and reagents involved in identifying inorganic and organic materials in tissues. The book will probably be used as a text in histological technique courses and may be used in conjunction with sketchy instructions found in other sources. Although illustrated, there are areas which would profit from additional drawings and diagrams. A fine reference book for the high school biology laboratory.

P.K.

SCHIFFERES' FAMILY MEDICAL ENCYCLOPEDIA, Justus J. Schifferes, 619 pp., $ .50, Permabooks, New York, 1959.

A paper-back "Doctor's Book" with a combination encyclopedia-dictionary approach. Liberally illustrated with line drawings, the range of topics covered is quite large. The book seems to have the sponsorship of a great many recognized health agencies. First-aid advice is built into the book in many places.

P.K.

OUTLINE OF HUMAN GENETICS, L. S. Penrose, 146 pp., $2.50, John Wiley & Sons, Inc., New York, 1959.

An English book which summarizes and outlines some of the essential and latest information on the subject. As usual, the style is an easy-to-

read one, although many difficult and modern concepts are taken up. The treatment of eugenics is an interesting one which should stimulate a great deal of discussion in a class. Although the book is illustrated, mostly by pedigree charts, this seems to be one of the weak points of this endeavor. Elementary genetics is taken up step by step, but human examples are consistently used. This should be a good book for the science reference shelf.

P.K.

MODERN GENERAL SCIENCE, Alan H. Humphreys, 256 pp., $2.00, The Steck Company, Publishers, Austin, Texas, 1959.

A combination text and workbook for general science. The scope of the subject is almost alarming, but the review of biology was of most interest to this reader. It is really astounding how many concepts and fundamental ideas are taken up in a brief space! The treatment of photosynthesis is the most complex—and probably the most accurate—that I have seen in any of the current high school texts. While genetics is taken up, evolution is ignored. High school biology teachers should look this over—as they should other general science books—to see what their students *should* know before they have them.

P.K.

GROWTH DIAGNOSIS, Leona M. Bayer and Nancy Bayley, 240 pp., $10.00, University of Chicago Press, Chicago, Illinois, 1959.

High school teachers, of biology especially, will probably have a substantial interest in the physical growth aspects of adolescence. This book will be the standard reference book in this field, especially when predictions as to future height and weight are called for. It is a book employing anthropometric techniques to diagnose growth variations from the normal patterns and to make predictive tables. For some time the old "correct" weight for specific height tables have been outmoded by new research. This work attempts to show how longitudinal growth research has produced some new tables.

In short, this book shows how anthropology and medicine can cooperate to produce solid research of value to physicians and health authorities who must assess the growth pattern of

children, and to teachers and counselors who need to reassure many children about their growth.

Biology teachers may find some project ideas here, but they should primarily find the book an interesting source of hard to find data on the physical growth of adolescents.

P.K.

THE SENSE OF SMELL, Roy Bedichek, 264 pp., \$3.95, Doubleday & Company, Inc., Garden City, New York, 1960.

A naturalist's point of view of one of the organism's amazing senses. It is chock full of unusual and interesting information culled from a variety of sources starting with ancient literature. Some unit headings will give some idea of the book: Impact on the Emotions; The Nose of Prejudice; Nature's Noses; and The Mechanism. An interesting book for the school library.

P.K.